CONSTRUCTION
ESTIMATES AND COSTS

CONSTRUCTION ESTIMATES AND COSTS

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CONSTRUCTION ESTIMATES AND COSTS

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PREFACE TO THE SECOND EDITION

In the preparation of this second edition, every effort has been made to bring up to date the information concerning wages and prices. This information is approximate only. Construction wages in 1946 were considerably higher than in 1939 and are still increasing. Materials are very uncertain with respect to kinds available, quality, quantities, and prices. Increases in prices may be expected.

More than half of the diagrams have been redrawn and most of the illustrative estimates have been revised in order to include the upward revisions in wages and prices.

H. E. PULVER.

MADISON, WIS.,
March, 1947.

PREFACE TO THE FIRST EDITION

This book has been written primarily for practical men who wish to study methods of estimating construction costs. The methods given in this book have been developed by the author as a result of several years of teaching estimating construction costs to hundreds of men residing in nearly every state of this country. Many illustrative estimates have been included so that the application of these methods may be thoroughly understood.

In this book, attention is called to variations in the time required by different men to do certain work as well as to variations in hourly wages.

The time in hours required to do a certain amount of work is emphasized instead of the amount of work done per hour. This permits the use of multiplication instead of division, and tends to reduce the number of mathematical errors. The author has found that men make fewer mistakes in multiplication than in division.

The information given in regard to prices of materials is approximate only. This information is included so that the reader or student may have some general information in regard to prices prevailing in 1939 when the text was written.

Many tables have been included. Most of the tables relating to labor give both the time in hours required to do work and the amount of work done per hour.

Many diagrams have been prepared and included so that the preparation and use of simple diagrams for estimating purposes may be understood. Practically all the diagrams are straight-line diagrams. Such diagrams are easy to construct and to use.

Every effort has been made to make the tables and diagrams comprehensive, accurate, and useful. The author would appreciate receiving notice of any errors in these tables and diagrams.

H. E. Pulver.

Madison, Wis.,
January, 1940.

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CONSTRUCTION ESTIMATES AND COSTS

Estimating of construction work may be defined as the process of calculating the quantities and costs of the various items entering into the work.

As the estimate is made before the work is done, the estimated cost is only the probable cost and is never the actual cost. The agreement of the estimated cost with the actual cost will depend upon the skill and judgment of the estimator. Skill implies the accurate use of good estimating methods, and judgment implies the correct visualization of the work as it will be done.

CHAPTER I

ESTIMATING IN GENERAL

1. Kinds of Estimates.—An estimate of the cost of a construction job is the probable cost of that job as computed from the plans and specifications. There are several kinds of estimates. Some of the ones more commonly used are the following:

A *detailed* estimate is one which includes the quantities and costs of everything that a contractor is required to provide and do for the satisfactory completion of the work. A detailed estimate is the best and most reliable form of estimate that can be made. There are two ways of making a detailed estimate.

In the *unit-quantity* method, all the costs of a unit quantity of the item considered are found and summarized. Then the total cost for the item is found by multiplying the cost per unit quantity by the number of units. For example, on a simple concrete job, the total cost of 1 cu. yd. of concrete would be first found and then this unit cost multiplied by the number of cubic yards in the job in order to obtain the total estimate. This method presents the information in such a way that unit

costs on various jobs may be readily compared and also that the total estimate can be easily corrected for variations in quantities.

In the *total-quantity* method, the total quantities of each kind or class of material and labor needed are first found, then these quantities are multiplied by their individual costs, and the results summed up. For example, on a simple concrete job, the costs of all the materials, all the labor, all the plant, etc., would be found separately and then added to obtain the total estimate.

An *approximate* or *short-cut* estimate is an approximate or rough estimate made to obtain an approximate cost in a short time, or to check roughly the costs found by more accurate methods. Such an estimate is not very reliable. Examples are the square-foot and cubic-foot methods of estimating building costs.

A *complete* estimate is one that includes all costs relating to the work in addition to those included in the main contract and subcontracts. For example, a complete estimate of a large office building would include the following items: land, legal fees, architect's fees, main contract, subcontracts, extras, financing, interest, insurance, and taxes during construction.

A *quantity survey*, sometimes called a *quantity* estimate or materials *take-off*, is a complete estimate of the quantities of all the materials required. In some localities, a "quantity surveyor" prepares a list of materials for any given building, and all the contractors use this list when preparing their bids. The contractors make their own estimates for material prices, labor, plant, overhead, and profit.

A *contractor's* estimate is made by the contractor for determining the price or prices to be bid. It is usually a carefully prepared detailed estimate.

An *architect's* or *engineer's* estimate is one made by the architect or engineer usually for the purposes of financing the work and for checking bids made by contractors.

Progress estimates are estimates made (by the engineer) at periodic intervals during the progress of the work for determining the amounts of partial payments to be made to the contractor. On large contracts, such estimates are commonly made each month and, hence, are frequently called *monthly* estimates. Usually 10 to 15 per cent of the amount due the contractor at any payment is retained to ensure the satisfactory completion of the

work by the contractor and also as a fund to cover errors and contingencies.

A *final* estimate is one made (by the engineer) at the completion of the contract. The purpose of this estimate is to determine the amount of final payment due the contractor and also to determine the exact quantities that have been used. Such an estimate is essential when there are extras on the work or when the contractor is paid according to the number of units of work, such as cubic yards of excavation or square yards of pavement.

2. Qualifications of an Estimator.—A good estimator of construction costs should possess the following qualifications:

1. A knowledge of the details of construction work.
2. Experience in construction work.
3. A fund of information relating to materials required, labor-hours required, plant needed, overhead problems, and costs of all kinds.
4. Good judgment in regard to different localities, different jobs and different workmen.
5. A good method for preparing an estimate.
6. Ability to do careful, thorough, painstaking, and accurate work.
7. Ability to collect, classify, and evaluate data relating to estimating.
8. Ability to visualize all the steps during the process of construction.

Good instruction will help a man to become a good estimator. He can be instructed in a good method of preparing estimates, he can be taught how to make the needed computations, he can be shown what items to include in the estimate, and he can be cautioned concerning errors that he may make.

He cannot be taught experience or judgment. He must obtain his own practical experience and develop his own faculties of judgment. Some men learn rapidly by their own experiences and the observed experiences of others, and other men learn slowly. Some men develop good judgment in their lines of work in a comparatively short time, and others require more time.

3. Collection of Data.—The collection, classification, and evaluation of data relating to estimating is important. The estimator should take notes and keep cost records on as many jobs as he can. The notes and data should be complete, espe-

cially in regard to quantities and prices of materials; labor conditions, work, and wages; weather and job conditions; plant costs; delays and their causes; and conditions relating to overhead costs. The data collected should be arranged in an orderly manner and conveniently filed for reference.

4. Tables and Diagrams.—Nearly all estimators use tables and diagrams to simplify their work. Some estimators like tables; others like diagrams; and others like both tables and diagrams. The use of both tables and diagrams should be learned, as available cost data may be in either tabular or diagrammatic form. Almost any set of data may be expressed either in the form of a table or in the form of a diagram. Interpolations of values are often made more easily on diagrams than in tables. The selection of tables or diagrams to be used as an aid in estimating is a question for each individual estimator to decide for himself after he has studied both. Both tables and diagrams are used in this text, though more emphasis is placed on diagrams.

Data in tables should be arranged in an orderly manner and divided by lines or spaces so that the table will be easy to read. Some estimators like the tables to be arranged so that most of the reading is across the table, and others prefer to read up and down. Complicated tables and tables so large that they extend over several pages should be avoided.

When the data are presented in the form of diagrams, the diagrams should be simple and easy to read and use. In most instances, it will be found that the desired relations between the variables can be shown in the diagram by straight lines instead of curves. Straight lines are easier to compute, plot, and read than curves. Though only two points are needed to determine any straight line, at least three points should be computed and plotted. All three points should be in the same straight line. If all three points are not in the same straight line, there is at least one error in the computations. The straight lines or curves in a diagram should not be too close together for ease in reading. Also, when practical, the straight lines or curves should cross the horizontal and vertical "grid" lines of the diagram at an appreciable angle, say about 20 to 70 deg.

5. Material Diagrams.—In the material diagrams, the relations among quantities, prices, and costs are readily seen at a glance. In most of the material diagrams, the cost of the mate-

rial is usually given along the horizontal scale, the cost per unit to be used in estimating is given along the vertical scale, and each straight-line "curve" represents a certain quantity per estimating unit.

A typical simple material-cost diagram is shown in Fig. 1-1. This diagram may be used for estimating the lumber cost per

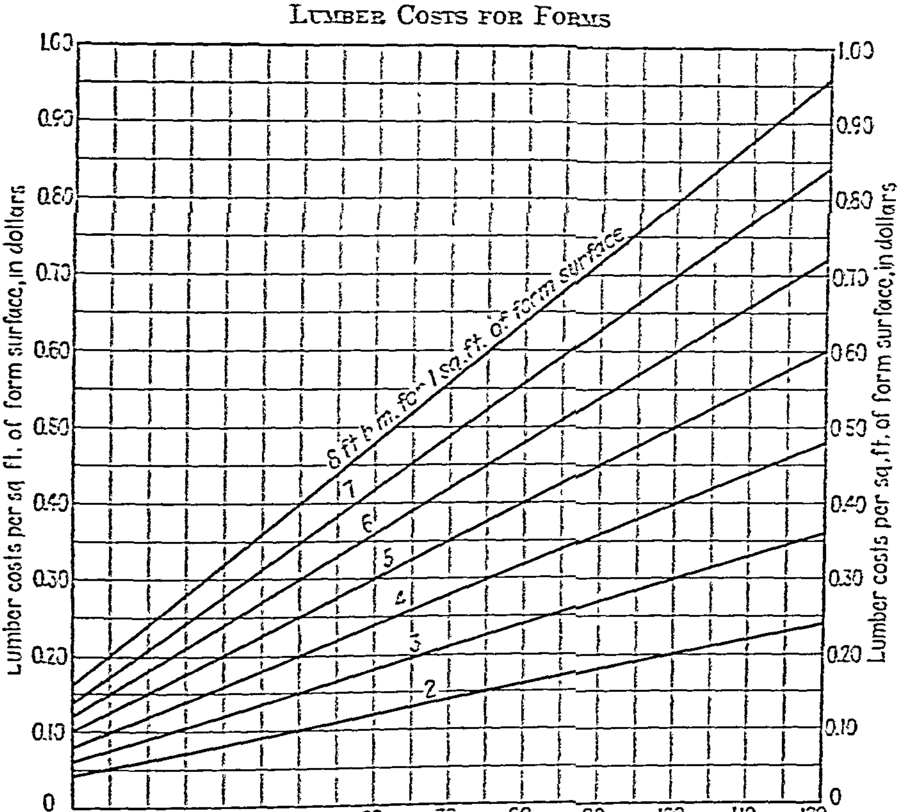

FIG. 1-1.—Cost of form lumber in dollars per square foot of form surface.

square foot of form surface for concrete. The horizontal scale gives the cost of lumber in dollars per 1,000 ft. b.m. The vertical scale gives the lumber cost in dollars per square foot of form surface. Each straight line represents a certain amount of board feet of lumber required for 1 sq. ft. of form surface.

To compute three points or values for one of the straight lines, consider that 4 ft. b.m. of lumber are required for 1 sq. ft. of form surface. At \$20 per 1,000 ft. b.m., the cost per square foot of

same straight line. Values for the other straight lines may be found in a like manner.

For an illustrative example of the use of this diagram, assuming that the hourly wage is $1.20 and the rate of work for assembling and erecting forms is 9 man-hours for 100 sq. ft. of form surface, the diagram shows that the labor cost is $0.11 per square foot of form surface. If there were 380 sq. ft. of form surface, the labor cost for assembling and erecting the forms would be $0.11 × 380, or $41.80.

7. Preliminary Investigations (Visiting the Site).—Before preparing an estimate, the estimator should visit the site (or have a responsible party visit it for him) and make a study of the conditions there. For example, if the construction of a large building is planned, the estimator or his representative should visit the site; note the location of the proposed building; get all available data regarding the soil; make a sketch of the site showing all important details; decide on the best location for the plant and the materials storage yard; partly plan the construction plane (visualize it); obtain information concerning light, power, and water; obtain information regarding local ordinances and regulations; secure information concerning banking facilities; note conditions of roads and streets leading to railway yards and to material dealers; investigate cost of local haulage; consult with material dealers regarding prices and deliveries (if local dealers are to be used); study local labor conditions in regard to wages, supply, and general efficiency of local workmen; and investigate boarding and rooming places for workmen (if workers have to be imported).

8. Five Subdivisions of Estimating.—The work of estimating may usually be divided into five essential parts, or subdivisions, as follows:

1. Materials. Estimating quantities and costs.
2. Labor. Estimating labor-hours and costs.
3. Plant. Estimating amount and kind of equipment needed and costs.
4. Overhead. Determining items included and estimating costs.
5. Profit. Estimating percentage for time, place, and job.

In some estimates, one of these five main items may be negligible, and some subitem may become large enough to be con-

sidered by itself. For example, in estimating excavation, the cost of the soil excavated may be zero, but the cost of transportation of this soil is large and may be considered as a main item.

9. Estimating Materials.—The preparation of a list of materials is known as the "take-off." The estimator takes off the various materials from the plans and specifications, and tabulates on "quantity sheets" all these different materials as to kind, number, size, weight, volume, or other units used. If the job is a large one and many quantity sheets are required, the total quantities for the various items are brought forward in condensed form to "summary" sheets, and totals obtained for each kind or class of material. These totals are used in preparing the final estimates.

In some places, a "quantity surveyor" prepares a complete estimate or list of the quantities of all the materials required (called a "quantity survey"), and the contractors use this list or estimate when preparing their bids.

When estimating material costs, the costs of the materials at the job are usually used. This cost includes first cost, freight, unloading, cartage, storage, inspection, testing, and insurance.

10. Estimating Labor.—When preparing labor estimates, due allowances must be made for variations in wages, for variations in the length of time (hours) required to do a certain item of work, for variations in working conditions, and for variations in the classes (skilled and unskilled) of labor required for different kinds of work. Some allowance should also be made in regard to the probable labor supply and demand.

Several years ago, the day was usually selected as the unit of time, and labor estimates were based on the amount of work done per day and the daily wages. At the present time, the hour is the most satisfactory unit of time because the effects of work days of varying lengths (6, 7, 8, 9, or 10 hr.) are eliminated and also because most wages are now expressed as hourly wages. The hour is used in this text as the unit of time for estimating labor.

The length of time required to do a certain piece of work may vary considerably owing to the skill and mental attitude of the workman and also to the working conditions on the particular job. In some localities, union rules and regulations tend to limit the hourly output of the worker. When work is plentiful,

rents, general insurance, workmen's compensation insurance, social security tax, office equipment and stationery, telephone and telegraph, interest, taxes, legal expenses, expenses of plans and specifications, traveling expenses, and sundries. Overhead costs also include the salaries (or portions of salaries) of managers, superintendents, estimators, solicitors, engineers, inspectors, clerks, timekeepers, stenographers, draftsmen, and watchmen, chargeable to the particular job. If desired, overhead costs may be divided into general overhead (such as office and yard costs) and job overhead.

Some contractors charge the salaries of foremen to labor, and others charge these salaries to overhead. In general, if the foreman is with his gang continually and works with them to some extent, his salary should be considered a labor item. However, if the foreman does not work with any gang, or if his time is divided among two or more gangs, his salary should be charged to overhead. Either way is satisfactory provided that the method used is understood and the foreman's salary item is included in the estimate.

Total overhead expenses may vary from 10 to 30 per cent of the total cost, or from 15 to 50 per cent of the labor cost. Workmen's compensation and liability insurance is desirable (and is usually required) and usually varies from about 5 to 12 per cent of the total labor pay roll. The rates for this insurance vary greatly for different kinds of work and in different states. The social-security tax (in 1946) is 2 per cent of the pay roll, 1 per cent being deducted from the employee's wage. Cost of inspection varies from 2 to 3 per cent of the total cost. Plans and specifications cost about $2\frac{1}{2}$ or 3 per cent of the total cost. When an architect or consulting engineer has charge of the plans and specifications and of the construction and inspection, his fees may vary from 5 to 8 per cent of the total cost.

Overhead expenses are sometimes apportioned to the several parts of a job according to the sum of the materials, plant, and labor costs of these parts. Another method is to apportion the overhead expense according to the labor-hours or the labor costs of the several parts of the job, though occasionally some of the overhead expense may be assigned to the materials or to the plant. On small jobs, the overhead expense is usually figured as a certain percentage of the labor costs, or as a certain percentage

of the sum of material, labor, and plant costs. Any reasonable method of computing and apportioning overhead expenses will be satisfactory if the method used is properly understood and correctly applied.

Some discussion of overhead costs is given in each of the following chapters that relate to the estimating of costs for particular types of work (concrete, masonry, steel, plumbing, etc.). A general discussion is included in Chap. XVIII.

13. Estimating Profit.—Last, but not least in importance, is the profit. The amount of profit is usually expressed as a percentage of the total estimated cost of the job. This percentage usually varies from about 8 to 15 per cent, depending on the contractor's desire for the work, what he thinks is fair, and what he thinks he can get. For small jobs, 15 per cent is a common figure for profit, with 12½ per cent for medium jobs, 10 per cent for large jobs, and possibly 8 per cent for very large jobs. The percentage of profit added also depends, to some extent, on the risks and unforeseen difficulties of the job, and on how often payments are to be made and in what amounts. On large jobs, payments up to about 85 per cent of the total work done may be made each month.

14. Sources of Error.—There are many ways in which errors may enter into an estimate. Some of the more common errors are the following:

Errors in arithmetic. Addition, subtraction, multiplication, division, and decimal points.

Errors in copying items from one paper to another.

Omission of items of materials, labor, plant, or overhead. The items should be checked against a "reminder" list. For example, one contractor omitted one floor in a 10-story building estimate, one forgot the interest charge on the money he had to borrow, another omitted the accident and liability insurance, another forgot his foreman's wages.

Errors in estimating the lengths of time required to do certain items of work by different workmen and gangs.

Errors in estimating wages of men.

Errors in estimating quantities of materials.

Errors in estimating wastage of materials.

Errors in estimating prices of materials, including effects of rising, falling, and steady markets on prices.

derricks, engines, planks, runways, and such hand and small tools as gloves, shovels, picks, crowbars, pinch bars, hand hooks, saws, hammers, axes, and small special tools. Hand trucks may be needed on some jobs.

Ordinary hand tools rarely last the contractor more than a year because of being worn out, lost, misplaced, or "missing." Hand trucks, barrows, and like tools may last up to two or three years, depending on the amount and kind of use.

When computing equipment or plant costs, it is essential to include such costs as depreciation, interest, repairs, operation, erection and takedown, and the costs of moving the equipment from the contractor's yard or storehouse to the job and back again. Power-equipment operation should include the costs of operators, grease and oil, gasoline, coal, and electricity, as the case may be.

4. Transportation Costs.—The costs of transporting materials from one place to another are usually considered separately from the costs of handling (unloading, loading, and piling). Materials may be moved from one place to another by carrying by hand; by use of hand vehicles such as hand trucks, carts, and barrows; by horse-drawn vehicles such as carts, dump wagons, and drays; by motor trucks; by boats; by railways; by airplanes; and by combinations of these agencies. The contractor may have and use his own equipment, or he may hire equipment from others or contract with others to do the work.

When the materials are transported by freight or express by means of boats, railways, or trucks (as the case may be), such costs are usually included in the estimate as one item. However, when the contractor uses his own equipment, his transportation costs may, if he desires, be subdivided. For example, the costs of transporting materials by autotrucks may be divided into labor (drivers and repairmen) and equipment (interest, depreciation, gas, oil, tires, repairs, etc.). Most estimators, when preparing an estimate, would not go into such detail, but would consider a truck and driver to cost so many dollars per hour. Of course, when computing this hourly rate, all the various cost items would be considered, but this hourly rate would not be recomputed in detail for each estimate for hauling materials.

5. Overhead Costs.—Overhead costs should include all such items as are mentioned in Art. 12 of Chap. I that apply to the

particular job for which the estimate is being prepared. Overhead costs may be based on the sum of the handling and transportation costs, or may be based on handling costs or on labor costs alone as desired.

In the absence of more specific data, 8 to 25 per cent of the sum of handling and transportation costs should be added for overhead. If the overhead is based on the labor costs alone, the percentage may vary from 12 to 50.

When the handling and transporting of materials are considered as a complete job, the overhead costs must always be included. If the handling and transporting of materials are considered as parts of the job, the overhead costs may be included by adding them as a separate item when summarizing the total estimate for the complete job.

6. Profit.—Profit is usually added as a separate item after all the cost estimates for the different portions of the job have been prepared and totaled. If the handling and transporting of materials are considered as a complete job, allowance should be made for profit. However, no allowance need be made for profit if the handling and transporting of materials are considered as parts of a job.

7. Summary.—*The total cost of handling and transporting materials* may be summarized as follows. If unit costs are desired (say per cubic yard or per ton), these unit costs may be found by dividing the total costs by the corresponding number of units.

Item	Total Estimated Cost	Unit Cost
Handling (labor and equipment)......	$	$
Transportation (labor and equipment).		
Overhead (if not cared for otherwise)..		
Profit (if any is to be included).......		
Total..............................	$	$

8. Unloading, Loading, and Piling by Hand Labor.—Many construction materials are unloaded, loaded, and piled by hand. In this article, only a few materials will be considered, but the principles involved are the same for various other materials.

The time rate of work may be given in terms of the hours of labor per 100 units (sacks or block), per ton, per 1,000 ft. b.m.,

By using Diagram 2-2, the labor costs per 1,000 units or sacks are found to be \$6.60, or \$0.0066 per bag. Then the labor costs for 800 sacks would be \$0.0066 × 800, or \$5.28.

Illustrative Estimate.—Prepare an estimate of the labor costs of unloading 8,500 face brick from freight cars to trucks. Trucks can back up to car doors so that the brick can be carried from the cars and piled on the trucks. Brick tongs will be used, and 5 brick will be handled at a time. Labor wage is \$0.575 per hour.

The time required to pick up the brick, take a few steps, pile on the truck, and return may be taken at about 2.25 hr. per 1,000 brick, fair workmen and no delays being assumed. The time required for 8,500 brick would be (2.25 ÷ 1,000) × 8,500, or 19.125 hr. The labor costs would be

$$\$0.575 \times 19.125, \text{ or } \$11.$$

By using Diagram 2-2, the labor costs per 1,000 units or brick are found to be \$1.30. The labor costs for 8,500 brick (8.5 thousand) would be \$1.30 × 8.5, or \$11.05 (say \$11).

Illustrative Estimate.—Prepare an estimate of the labor costs of unloading 68,000 ft. b.m. of lumber from flatcars and piling it on ground near the track. The lumber is in the form of 1-in. boards, 2-by-4's, and 2-by-6's, varying in length from 12 to 16 ft. Labor wage is \$0.65 per hour.

On the assumption that the men work in pairs and that they are average workmen, the time (labor-hours) required to unload and pile 1,000 ft. b.m. may be taken as about 0.8 hr. (*i.e.*, 2 men working together would require 0.4 hr. for 1,000 ft. b.m.). Total time (labor-hours) required would be (68,000 ÷ 1,000) × 0.8, or 54.4 hr. The labor costs would be \$0.65 × 54.4, or \$35.36.

By using Diagram 2-1, the labor costs per 1,000 ft. b.m. are found to be \$0.52. The labor costs for 68,000 ft. b.m. would be \$0.52 × 68, or \$35.36.

10. Shoveling.—The cost of shoveling depends upon the kind of material (heavy, medium, or light), condition of material (loose or compact, dry or wet), vertical distance or lift, kind of shovel used, as well as upon the skill and inclination of the workmen. Working conditions, such as sureness of footing and freedom of movement, also affect the rate of work.

The presence of a foreman is usually desirable even on small jobs so that the work will be properly supervised and the men kept busy. With small gangs, say about five men or less, the foreman can work with the men. The amount of shoveling that the foreman can do with a small gang will depend largely upon the time required of him to lay out and direct the work. However, with larger gangs, the work will usually proceed more rapidly if the foreman directs the work and keeps the men busy but does no shoveling himself.

There is a great variation in the rates at which workmen will work. It is easier to shovel from smooth ground or a smooth platform than from a rough or muddy surface. The proper size and kind of shovels or forks should be provided. The shovel should be of such size and shape that it will hold a load of about 22 lb. There is a knack to shoveling which a workman must learn (or be taught) before he can become efficient.

If there is much shoveling to be done on a construction job, the foreman in charge of the shoveling gang should select the shovels

TABLE 2-2.—SHOVELING LOOSE MATERIALS

Material	Work	Cubic yards		Tons	
		Cu. yd. per hr. per man	Labor-hr. per cu. yd.	Tons per hr. per man	Labor-hr. per ton
Sand..........	From car or truck to ground, from car to truck, or from pile to pile at same elevation	1.50–3.00	0.35–0.70	2.00–4.00	0.25–0.50
Crushed stone..		1.00–2.50	0.40–1.00	1.25–3.00	0.35–0.80
Gravel........		1.00–2.50	0.40–1.00	1.25–3.25	0.30–0.80
Cinders.......		2.00–4.00	0.25–0.50	1.75–3.50	0.30–0.60
Loam.........		1.25–2.75	0.35–0.80	1.65–3.50	0.30–0.60
Sand..........	From ground to car, truck, or wagon where lift is 4 ft. or less	1.25–2.50	0.40–0.80	1.65–3.50	0.30–0.60
Crushed stone.		0.75–2.25	0.45–1.35	0.90–2.75	0.35–1.10
Gravel........		0.75–2.25	0.45–1.35	0.95–3.00	0.35–1.05
Cinders.......		1.50–3.50	0.30–0.65	1.25–3.25	0.30–0.80
Loam.........		1.00–2.50	0.40–1.00	1.35–3.35	0.30–0.75
Medium soil...		0.75–2.00	0.50–1.35	1.00–2.65	0.40–1.00
Hard soil or clay.........		0.60–1.50	0.65–1.65	0.80–2.00	0.50–1.25
Hard pan......		0.50–1.25	0.80–2.00	0.70–1.65	0.60–1.45
Sand..........	From ground to car, truck, or wagon where lift is 4 to 6 ft.	0.75–2.00	0.50–1.35	1.00–2.75	0.35–1.00
Crushed stone..		0.50–1.75	0.60–2.00	0.65–2.25	0.45–1.50
Gravel........		0.50–1.75	0.60–2.00	0.65–2.50	0.40–1.50
Cinders.......		1.00–3.00	0.35–1.00	0.85–2.75	0.35–1.20
Loam.........		0.65–2.00	0.50–1.55	0.85–2.75	0.35–1.20
Medium soil...		0.50–1.50	0.65–2.00	0.65–2.00	0.50–1.55
Hard soil or clay.........		0.40–1.25	0.80–2.50	0.55–1.65	0.60–1.80
Hard pan......		0.30–1.00	1.00–3.35	0.40–1.35	0.75–2.50

to be used for different materials, and show how these shovels should be handled for the best results. In some cases, it may pay to make time and motion studies of shoveling.

The unit of work is usually the cubic yard with the materials measured in a loosened condition, though the materials may be measured in a compact form in some cases. However, when materials are purchased by weight instead of volume, the ton of 2,000 lb. may be used as the unit of measurement.

Table 2-2 shows variations in shoveling rates under different working conditions and using men of varying efficiency.

When the total lift is over 6 ft., platforms may be used so that any one lift or stage will not exceed 5 or 6 ft.

In Table 2-3, the approximate weights per cubic yard of some of the materials are given. The weights per cubic yard will vary with different kinds of materials and will depend on their looseness or compactness, and also on their wetness or dryness.

TABLE 2-3.—WEIGHT PER CUBIC YARD

Material	Weight per Cubic Yard, Pounds
Sand	2,200–3,000
Gravel (screened)	2,200–2,800
Gravel (bank run)	2,400–3,200
Crushed stone	2,000–2,700
Cinders (very variable)	1,600–2,500
Loam or dirt	2,200–2,800

Diagram.—Diagram 2-3 (page 537 may be used for finding the cost per cubic yard or per ton of shoveling materials when the hourly wage is known and the labor-hours required to shovel 1 cu. yd. or ton of material can be assumed correctly.

11. Illustrative Estimate.—Prepare an estimate of the labor cost of unloading a railway car containing 45 tons of gravel. The gravel is to be shoveled from the car to trucks. The labor wage is $0.90 per hour.

On the assumption that there would be no delays on account of the trucks and that the men of the gang of shovelers are good workmen, about 0.75 labor-hours will be required for shoveling 1 ton of gravel into the trucks. Then the cost of unloading 45 tons will be $0.90 × 0.75 × 45, or $30.40.

By using Diagram 2-3, the labor cost of unloading 1 ton of gravel is found to be about $0.675. The labor cost of unloading 45 tons would be $0.675 × 45, or $30.38.

12. Unloading and Loading Materials with Power Equipment. There are many types of power equipment available for handling materials. These types may be classified according to kind

(as belt, bucket, or scraper), power (as steam, electric, gasoline, or diesel), weight in tons, size of conveyor (as size or capacity of bucket, scoop, or scraper in cubic feet or cubic yards of material), or capacity in work units per unit of time (as cubic yards or tons per hour).

In this book, no attempt will be made to describe the various types of power equipment for handling materials. Several hundred pages would be required for adequate descriptions. For such descriptions, the reader is referred to books on construction equipment and to the catalogues of the various manufacturers.

Perhaps the best classification is the capacity of the machine in hours per unit of work or work units per hour. In the absence of better data, the manufacturer's rated capacity may be used and modified as required by the particular job. The manufacturer's rated capacity is the hours required to do a certain amount of work or the amount of work that the machine may be reasonably expected to do per hour when operated by a good workman and under average working conditions. On most jobs, the actual working time may vary from about one-fourth to three-fourths of the working hours because of necessary machine movements and delays caused by repairs, waits (as for trucks), and other reasons.

When estimating the time in hours required to move a certain quantity of a material, it is necessary to know the load per movement of the machine and the number of movements per minute or per hour. It is difficult to make an accurate estimate unless the estimator knows the machines, crew, and materials, and can make an accurate guess as to working conditions.

Here are some observations (taken a few years ago) in regard to handling earth.

A derrick with a ½ cu. yd. grab bucket averaged 16 cu. yd. per hour.

A crane with a ½ cu. yd. grab bucket averaged 10 cu. yd. per hour.

A crane with a ½ cu. yd. grab bucket averaged 27.5 cu. yd. per hour.

A locomotive crane with a 1 cu. yd. clamshell bucket averaged about 40 cu. yd. per hour.

A 2 cu. yd. dragline scraper on a 250-ft. cable way averaged about 60 cu. yd. per hour.

The costs of power equipment used for handling materials includes such items as transportation to and from the job, erection and takedown, interest, depreciation, rents (if rented), insurance, maintenance and repairs, lubrication, fuel or power, labor of operators and other workers, and overhead. Almost any machine, no matter how small, requires the services of at least one man. Larger machines may require the services of several men. For example, a small power loader (buckets on endless chains), such as may be used in a coalyard, requires the services of a man to see that material is supplied to the machine and that the machine is kept operating efficiently. A large steam shovel will need an operator and a fireman, and some laborers to assist in shovel movements and to do the necessary hand shoveling, etc. All machines have some overhead costs because they all require some supervision and office work.

There are several ways of figuring power-equipment costs. The unit cost desired is the cost of doing 1 unit of work, such as the cost of loading or unloading 1 cu. yd. of sand or 1 ton of coal. However, such a unit cost is not readily found without some preliminary computations. As most of the costs vary directly with the time that the machine is in use, the total hourly cost of operation is first found, and then the unit work costs are found by multiplying this hourly cost by the time required in hours to do the chosen unit of work, or by dividing this hourly cost by the number of units of work done per hour. This hourly cost of operation should include allowances for the cost of the machine when idle, the cost of moving the machine to and from the job, the cost of erecting and taking down the machine, the cost of general overhead and repair, and the cost of overhead. Some estimators use two hourly rates, one for the machine working and another when the machine is idle. Then the general expenses previously mentioned may be included in the hourly rate or may be added as a separate cost item.

The total hourly cost of operating power equipment (including labor costs of operator and workmen) may vary from about \$1 to \$20 or more, depending on the kind and size of the machine, cost of fuel or power, and number of operators and workmen required and their wages.

Diagrams.—Simple diagrams may be prepared showing the relations among total hourly costs, hours required to do certain

by going at a dogtrot. However, 100 ft. per minute is usually taken as the average walking speed as this rate allows for minor delays.

Diagram.—The cost of carrying materials by men may be shown in the form of a diagram, as in Diagram 2-7 (page 541). When preparing this diagram, a man was assumed to take 1 min. to pick up and lay down his load and 1 min. to walk 100 ft. These assumptions allow for small delays. Hence, the time required to transport one load 200 ft. and return would be $1 + 2 + 2$, or 5 min. Like reasoning gives 3 min. for 100 ft., 7 min. for 300 ft., 11 min. for 500 ft., etc.

15. Illustrative Estimate.—Estimate the cost of carrying 220 sacks of cement (1 sack weighs 94 lb.) 160 ft. Assume that each man carries one sack each trip. Men receive \$0.90 per hour.

Time required for one trip $= 1 + 1.6 + 1.6 = 4.2$ min.

Time required for 220 trips $= 4.2 \times 220 = 924$ min. $= 15.4$ hr.

Cost $= \$0.90 \times 15.4 = \$13.86$.

By using Diagram 2-7, cost of carrying one sack is about \$0.063. Then cost of carrying 220 sacks $= \$0.063 \times 220 = \$13.86$.

16. Transporting Materials by Vehicles.—The vehicles ordinarily used by a contractor for transporting materials are wheelbarrows, two-wheel hand carts, scrapers, two-horse dump wagons, and autotrucks. Transportation by freight and express are considered in later articles.

The cost of transporting materials by a vehicle depends upon several things such as the cost of operating the vehicle, the capacity of the vehicle, the load, the time required for loading and unloading, the speed of travel, and delays. The actual capacity of a vehicle is usually taken as about 80 per cent of the measured or rated capacity to allow for variations in materials and loadings. The time required for loading and unloading will vary on different jobs and for different vehicles, different materials, and different methods of loading. The travel speed will depend upon the particular vehicle, the road or path, and traffic and other conditions. Hence, for accurate estimating the estimator must have fairly exact information in regard to the variables present.

In Table 2-5, information is given in regard to various vehicles used for transporting materials. This information is approxi-

mate only. Further information concerning vehicles used in excavation is given in Chap. III, Table 3-7.

TABLE 2-5.—VEHICULAR DATA (APPROXIMATE)

Vehicle	Capacity, cubic yards	Economical haul, feet	Time, minutes		Rate of travel, feet per minute	
			Load	Unload	Loaded	Empty
Wheelbarrows.......	0.07–0.12	Up to 150	1.00– 3.00	0.20–0.30	75–125	100–175
Hand carts (2-wheel)	0.07–0.15	Up to 150	1.00– 3.00	0.25–0.40	70–125	100–175
Drag scraper (horse).	0.10–0.25	Up to 200	0.25– 0.75	0.20–0.50	150–200	175–225
Two-wheel scraper (horse)............	0.25–0.67	Up to 500	0.25– 0.75	0.20–0.50	150–225	175–250
Dump wagon (2-horse)............	1.0–2.0 (1–2.5 tons)	Over 400	1.0 –12.0	0.25–2.00	175–225	175–250
Autotrucks*.........	1–15.0 (1–20 tons)	Over 600	1.0 –20.0	0.25–2.00	10– 40	15– 50

* Rates of travel for autotrucks are in miles per hour.
Actual capacity is taken at about 80 per cent of rated or measured capacity.

Computation of Transportation Costs.—The computation of transportation costs by autotrucks, for example, may be divided into four steps.

1. Compute total operating cost of truck per hour, including such items as interest, depreciation, repairs and maintenance, tires, oil and grease, gasoline, labor (driver), and overhead.

2. Compute time in hours required for one round trip. This time includes time for loading, unloading, delays, traveling loaded, and traveling unloaded. Traveling time depends upon speed and speed depends upon the truck, the road, the driver, and the traffic.

3. Compute cost per trip. This equals cost per hour times hours for trip.

4. Compute unit costs by dividing cost per trip by number of units of material carried (cubic yards, tons, sacks, etc.).

A beginning estimator is apt to estimate the average truck speed at too high a value and to estimate the time lost in delays at too low a value. Plenty of time should be allowed for loading and dumping. Time lost in delays may be caused by waiting to load, waiting to unload, punctures and other tire trouble, engine

trouble, and accidents. Delays may average 10 min. or more per trip.

Diagrams.—Diagrams may be prepared showing the relations among the different variables such as distance or length of haul, speed of trucks, time for trip, time for loading and delays, cost per hour of truck, cost per trip, capacity of truck, and unit costs. As the relations among only three variables may be shown in a simple diagram, several diagrams are necessary.

Diagram 2-8 (page 542) shows the relations among length of haul loaded, time per trip (trucks hand loaded), and speed of trucks. When computing the time per trip, 1 min. is allowed for dumping or unloading, 3 min. for delays, and 20 min. for hand loading, giving a total of 24 min., or 0.40 hr. Note that total distance is twice the length of haul loaded.

Diagram 2-9 (page 543) is similar to Diagram 2-8 except that the trucks are power loaded. In Diagram 2-9, the loading time is taken as 3 min., unloading 1 min., and delays 5 min., giving a total of 9 min., or 0.15 hr. Other diagrams may be prepared, using other time allowances for loading, unloading, and delays.

Diagram 2-10 (page 544) shows the relations among cost per hour of truck, time required for trip, and cost of trip. Unit costs may be found by dividing the trip cost by the capacity of the truck (cubic yards, tons, sacks, etc.).

Diagram 2-11 (page 545) shows the relations among cost per trip, capacity of truck, and unit costs per cubic yard or per ton for trucks of varying capacities.

17. Illustrative Estimates.—The following two illustrative estimates show how transportation estimates may be prepared.

Illustrative Estimate.—Estimate the cost of transporting cement per sack from a railway siding to the job, assuming the following data: Truck capacity is 60 sacks of cement. Cost of truck and driver is $2.55 per hour. Average speed is 24 m.p.h. Length of haul is 8 miles. Time to load is 12 min. Time to unload is 12 min. Delays getting into position, for waiting turn, and for all other causes are 16 min. per trip.

One round trip = 2 × 8 = 16 miles
Time to travel 16 miles at 24 m.p.h. = 40 min.
Time for one round trip = 12(load) + 12(unload) + 16(delays)
+ 40(travel) = 80 min. = 1.33 hr.

Cost of one round trip = $2.55 × 1.33 = $3.40
Cost per sack of cement = $3.40 ÷ 60 = $0.0567

Illustrative Estimate.—Estimate the cost of transporting 120 cu. yd. of gravel from a material yard to a job 6 miles away. Truck capacity is

2.50 cu. yd. Cost of truck and driver is \$2.70 per hour. Average speed is 30 m.p.h. Truck is power loaded at material yard, and material is dumped at job.

Time to travel 6 miles and return at 30 m.p.h. = 24 min.
Assume time required for loading 3 min., unloading 2 min., and delays 4 min.
Total time for one round trip = 33 min. = 0.55 hr.
Cost of one round trip = \$2.70 × 0.55 = \$1.49
Number of trips = 120 ÷ 2.50 = 48,
Total cost = \$1.49 × 48 = \$71.50 (about)
Cost per cubic yard = \$71.50 ÷ 120, or \$1.49 ÷ 2.5 = \$0.60.

If desired. this estimate may be prepared by the use of Diagrams 2-9, 2-10. and 2-11. Although the time allowed for unloading is 1 min. more and the time for delays is 1 min. less than the time assumed when preparing Diagram 2-9, the total trip time will be the same. For a length of haul 6 miles (round trip of 12 miles) and a speed of 30 m.p.h., Diagram 2-9 indicates that about 0.55 hr. will be required. Diagram 2-10 shows that the cost of one trip will be about \$1.50, and Diagram 2-11 gives the cost per cubic yard to be about \$0.60. Total cost = \$0.60 × 120 = \$72.

18. Vertical Transportation of Materials.—Among the ways of moving materials vertically are carrying by men up inclines. stairs, or ladders; wheeling in barrows or carts up inclines; use of simple block and tackle and other types of hand hoists; and use of power hoists such as derricks, cranes, block and tackle with power vehicles, and elevators. The selection of the way to be used will depend on the equipment available, the job conditions, and the amount and kind of material to be elevated.

Carrying.—A workman will carry loads up to about 100 lb. up (and down) inclines at a speed of about 80 to 100 ft. per minute. the steeper the incline, the slower the speed, and the lesser the load. The vertical distance, however, will usually be less than half the inclined distance; hence, the vertical rate may be about 25 to 40 ft. per minute. The rate of carrying loads up or down stairs may vary from about 40 to 70 ft. per minute on an inclined line, or from about 20 to 35 ft. per minute vertically. A man will carry a load up or down a ladder at about 20 to 30 ft. per minute. The cost of transporting materials vertically by carrying may be estimated by the methods given in Art. 14 of this chapter, using vertical rates of speeds of from 20 to 40 ft. per minute as the case may be.

Hand Wheeling.—A man can push a wheelbarrow or a two-wheeled cart up an incline at an average rate of 70 to 100 ft. per minute measured on the incline or about 20 to 40 ft. per minute

vertically. The amount of material (load) carried by the barrow or cart will be less than that carried on the level; the steeper the incline, the less the load.

Hand Hoists.—Two or more workmen with block and tackle or other types of hand hoists or hand elevators may be used for elevating materials on small jobs where the use of power equipment is not justified. The number of pounds of material that a workman can raise a certain number of feet in an hour will depend upon his ability, the efficiency of the machine, the kind of material, the dead load or tare, and the working conditions.

On the assumption that 1 man power is the equivalent of $\frac{1}{6}$ hp., one man should be able to do $33{,}000 \div 6$, or 5,500 ft.-lb. of work in 1 min., or 330,000 ft.-lb. of work in 1 hr. On a hand-hoisting job, this energy may be used for loading, hoisting, and unloading. Of the energy used for hoisting, part will be used in overcoming friction and other machine losses, part in hoisting the container of the materials (dead load or tare), and part in hoisting the materials. Consequently, the part of the energy of the man used for actually hoisting the materials may vary from about 25 to 75 per cent of his total energy. This will amount to about 80,000 to 250,000 ft.-lb. of work per hour. That is, one man should be able to elevate 4,000 to 12,500 lb. of material a distance of 20 ft. in 1 hr., depending on conditions.

The hourly cost of elevating materials by hand power will depend upon the hourly wages of the men, the cost per hour of the equipment used, and in some cases, the overhead costs. Hand-equipment costs will usually be quite small.

Power Hoists.—The amount of materials that can be raised vertically by machine power will depend on the net load the machine can handle at one time, the distance the load is raised, the speed at which the machine operates, and the time required for loading and unloading. The machine or equipment costs should include such items as interest and depreciation (or rental), transportation to and from the job, erection and takedown, repairs and maintenance, and operation. When the hoist is used for hoisting several kinds of materials (as during the construction of a several-storied building), the costs may be apportioned among the kinds of materials hoisted, preferably according to the number of hours that the machine is used for hoisting each kind of material. The labor costs may include the labor costs of

loading and unloading materials on and off the machine, cost of machine operation (if not included in machine costs), and costs of erecting and taking down the machine (if not cared for otherwise). All overhead costs relating to the work should be included.

Because of the different types of hoisting machines, various kinds of materials, and different jobs and working conditions, it is impractical to attempt to prepare cost tables and diagrams. For example, two workmen with a small power chain hod elevator can elevate 2,000 to 3,000 brick a vertical distance of about 30 ft. in 1 hr. A power-driven two-barrow elevator with an operator (and necessary workmen for loading and unloading) can hoist 8,000 to 12,000 brick a vertical distance of about 30 ft. in 1 hr.

When preparing estimates of costs of hoisting materials by power equipment, the following procedure is suggested:

1. Compute all costs that are chargeable against the hoisting machine.
2. Compute all labor costs.
3. Compute overhead costs.
4. Sum all costs.
5. Estimate the number of hours that the hoist will be in operation.
6. Compute the total hourly operating cost.
7. Estimate the number of hours required to hoist a unit or a certain number of units.
8. Compute unit cost of hoisting the material, either by dividing total costs by total number of units of material, or by multiplying the hourly cost by the time required to hoist a unit.

19. Transporting Materials by Express.—The cost of transporting an article by express depends upon the distance transported, the weight of the package or shipment, the kind or class of material (ordinary, fragile, perishable, livestock, bulky, etc.), and the way it is packed or boxed.

First-class express rates are based primarily on distance. For determining the rates, the country is divided into blocks or areas and rates are established between blocks. The rates are not directly proportional to distance as they include terminal costs

one package, the terminal costs would be practically constant and the transportation costs would vary with the distance traveled.

The first-class merchandise rate between two blocks, for example, is the rate in dollars per 100 lb. for packages or shipments of 100 lb. or more, and for ordinary materials so packed that the packages may be readily handled without damage.

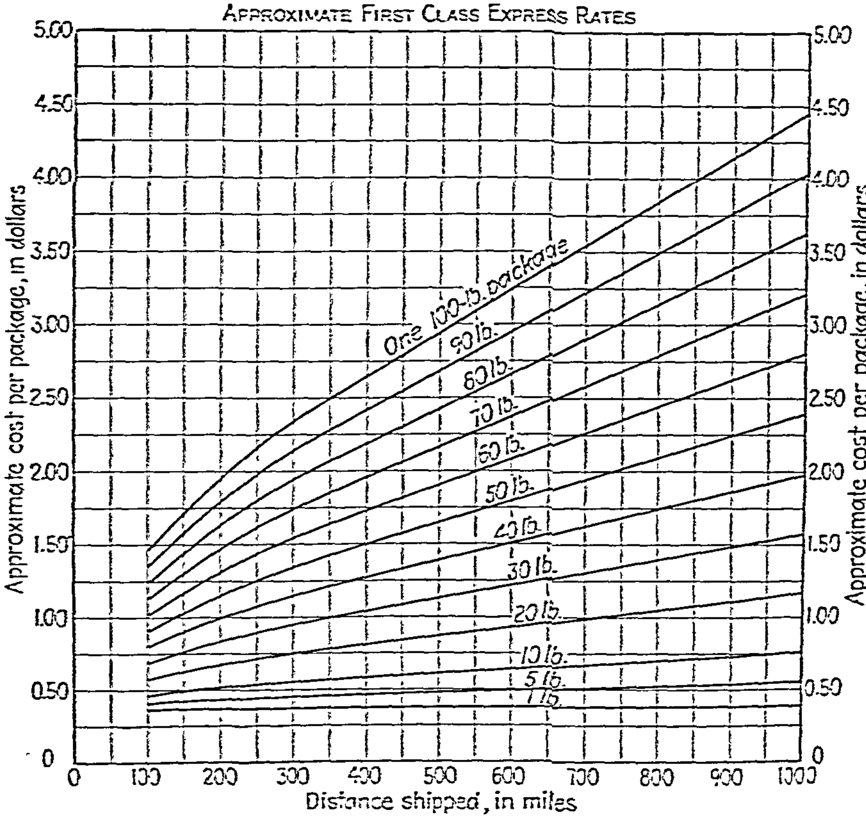

FIG. 2-1.—Approximate cost per package of shipping materials by first-class express. (U.S. tax of 3 per cent and emergency charge of $0.10 for each shipment are not included.)

Materials requiring special care in handling are charged higher rates which may vary from 1.5 to 3 or 4 times the first-class rates. In a few instances, there are special rates less than the first-class rates.

For packages weighing less than 100 lb., the charge is less than that for 100 lb., but not in proportion. The following formula may be used:

Each of these groups has adopted certain rates to be charged for all materials shipped in their territory. The Official (or Eastern) group includes all territory east of Lake Michigan and the eastern boundary of Illinois and north of the northern boundaries of Kentucky and North Carolina and, in some instances, the state of Illinois and the southern part of the state of Wisconsin. The Southern group includes all territory east of the Mississippi and south of the northern boundaries of Kentucky and North Carolina. The Western group includes all territory west of the Official and Southern groups.

Each of these groups has also adopted certain classifications or ratings for all the different kinds of freight. However, the class or rating may be different in different groups. The classifications in use in the three groups are called: Official Classification, Southern Classification, and Western Classification. The ratings, rules, and regulations of these three classifications have been published together under the title of "Consolidated Freight Classification." This book is the official book used in applying freight rates.

In classifying freight, certain abbreviations and symbols have been used. A list of these follows.

CHARACTERS APPEARING IN TERRITORIAL RATING COLUMNS

1	= first class	D1	= double first class
2	= second class	2½t1	= 2.5 times first class
3	= third class	3t1	= 3 times first class
4	= fourth class	3½t1	= 3.5 times first class
5	= fifth class	4t1	= 4 times first class
6	= sixth class	A	= class A
R25	= rule 25 class	B	= class B
R26	= rule 26 class	C	= class C
1¼	= 1.25 times first class	D	= class D
1½	= 1.50 times first class	E	= class E

ABBREVIATIONS APPEARING IN DESCRIPTIONS OF ARTICLES

L.C.L.	= less than carload	N.O.I.B.N.	= not otherwise indexed by name
C.L.	= carload	Lb.	= pounds
S.U.	= set up	Min. wt.	= minimum weight
K.D.	= knocked down		

An examination of the preceding list of characters shows that freight ratings are given by number, rule, and letter. In general, the higher the numerical rating, the lower the freight rate. Freight shipped in carload lots is given a higher numerical

rating than freight shipped in less than carload lots. In addition to the many classes listed and their accompanying rates, there are many special commodity rates applying on certain kinds of freight and between different stations.

The reader is referred to his local freight agent for a list of articles (materials) and the classification or rating for each article.

All these classes (as indicated by the characters listed) are not used by each group. The following table shows the classes used by each group and rates for each class expressed as percentages of the Class 1 rate. For example, if the rate for Class 1 in the official group was $0.84, the rate for Class 4 would be 50 per cent of $0.84, or $0.42.

TABLE 2-7.—CLASSES AND PERCENTAGES
Percentages are based on Class 1 rates for each group

Official Classification Group

Class	1	2	3 and R25	R26	4	5	6
Percentage	100	85	70	55	50	35	27½

Southern Classification Group

Class	1	2	3	4	5	6	7	8	9	10	11	12
Percentage	100	85	70	55	45	40	35	30	25	22½	20	17½

Western Classification Group

Class	1	2	3	4	A	5	B	C	D	E
Percentage	100	85	70	55	45	37½	32½	30	22½	17½

Figure 2-2 shows the *approximate* relations between first-class freight rates per 100 lb. and distance for the Official Classification or Group; and for East and West Traffic, east of the Rocky Mountains, for the Western Classification or Group. Once the first-class rate has been found, the rates for other classes may be found by means of Table 2-7. The minimum freight charge on any single shipment is usually $0.55.

As freight rates are subject to change from time to time, and as there are various special commodity rates in effect, the estimator should consult the local railway agent in order to obtain accurate information in regard to freight classifications and rates.

When shipping materials by freight over railroads, there may be other expenses in addition to the freight rates. In a few localities, the railroad will collect and deliver package freight. In most localities, the shipper or consigner must meet the expense of delivering the freight to the railroad company, and in some cases he must load the freight on the cars. At the destination, the consignee must pay for the haulage from the railroad, and in some instances he is expected to unload the freight. There may be switching charges when freight is loaded or unloaded from cars spotted or switched on sidings not located in the freightyards. Also, if a car is kept by the shipper (consignor) or consignee for

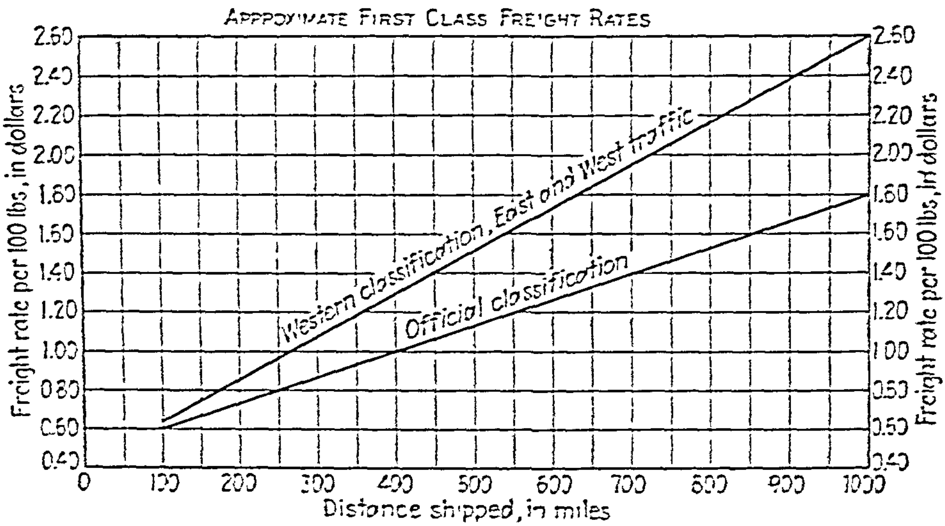

FIG. 2-2.—Approximate rates per 100 lb. for first-class freight. (U.S. tax of 3 per cent is not included.)

more than a certain length of time (usually two days), demurrage charges must be paid. These charges are usually $2 per car per day after the two free days.

The discussion so far has applied to freight shipped over railroads. Freight may also be shipped by boat. Freight rates by boat are often less than railroad rates, but the time required to transport a shipment a given distance is usually appreciably longer. When shipping by boat, the consignor usually delivers the freight to the wharf and the consignee takes the freight from the wharf at the end of the trip.

Freight may be shipped by autotruck. Trucking rates are often higher than railroad rates, but the trucks usually collect the freight from the shipper and deliver it to the consignee at

their respective places of business. The time required by trucks on short hauls is often less than the time required by railroads.

22. Combined Handling and Transportation of Materials.— The movement of materials from one place to another usually includes both handling and transportation. For economy, these two types of work should be combined so that the total cost of doing the work will be a minimum. In general, the use of more machinery will result in a saving of labor costs, and vice versa. However, the total combined costs of labor, equipment or plant, and overhead should govern.

The fundamental law is to select, arrange, and use the men and machinery so that the work will be done at a minimum cost. In some instances, the selection, arrangement, and use of machinery is limited to the equipment that the contractor has available for the job. In other instances, it may be advisable to rent or purchase additional equipment. Of equal importance is the selection of good workmen, their arrangement in gangs of the right number of men, and the use or supervision of the gangs so that the men will work efficiently and economically, especially when their work is combined with that of machines. Whenever practical, all men and all machines should be worked to their full capacity. The time lost by delays due to any cause should be reduced whenever possible. There is no special rule whereby the best combination of men and machines may always be determined by one computation. Often several combinations must be tried and computations made in detail before the most economical combination is found. A further discussion of the economical operation of men and equipment is given in Chap. XXI on Construction Management.

When estimating the cost of combined handling and transportation of materials by autotrucks, the hours required per truck load (or loads per hour) will depend upon the number of trucks loaded and unloaded per hour. For example, if 20 min. are required for loading and 15 min. for unloading one truck, only three truck loads can be handled per hour. The uloading gang will have a 5-min. wait between trucks. Also, if four trucks are provided per hour and only three can be handled per hour, each truck will have a wait of 20 min. per trip on an average (the loading time required for one truck). If five trucks per hour were

provided in this case, each truck would wait $(5 - 3) \times 20$, or 40 min. each round trip.

When considering gang times, the times of the gangs for loading and unloading should be taken as equal. For example, if the loading time is 20 min. and the unloading time is 15 min., only three trucks can be loaded per hour. Hence, only three trucks per hour will arrive at the unloading platform so that the unloading gang will have a 5-min. wait between trucks, and will be idle 5×3, or 15 min., out of every hour.

When computing the trip time required for a truck, this time will equal the loading time plus travel time loaded plus unloading time plus travel time empty plus delays. No two of these times have to be taken equal. The number of trucks needed per hour will equal 60 min. divided by the loading time in minutes (or divided by the unloading time if that is larger than the loading time).

In the preparation of any estimate for the cost of handling and transportation of materials, the four items mentioned in Arts. 1 and 7 of this chapter must be considered.

23. Illustrative Estimates on Combined Handling and Transportation of Materials.—The following four illustrative estimates show how cost estimates may be prepared for the handling and transportation of materials. In order to bring the costs up to 1946 levels, the labor wages and overhead costs may be increased by about 40 to 50 per cent and the truck and driver costs increased by about 25 to 40 per cent.

Illustrative Estimate.—Estimate the cost of unloading 226,000 ft. b.m. of lumber from freight cars, transporting 1 mile by truck, and piling in yard. Contractor has a gang of 3 men with 1 truck and driver. Capacity of truck is 2,000 ft. b.m. and average speed (allowing for small delays) is 16 m.p.h. The men ride back and forth on the truck. Assume cost of truck, driver, and 3 men to be \$5.60 per hour, and allow 15 per cent for overhead charges.

Solution: The three men working together would require about 0.45 hr. to load the truck, if it is assumed that the truck can back up to the car, and perhaps an equal time to unload and pile in the yard, if it is assumed that the lumber can be piled directly from the truck (see Table 2-1, page 19).

Time required for one trip = 0.45 (load) + 0.45 (unload)
+ 0.0625 (travel loaded) + 0.0625 (travel empty) = 1.025 hr.

Cost per hour of truck, driver, and gang, including overhead = \$5.60
× 1.15 = \$6.44

Cost of one trip = \$6.44 × 1.025 = \$6.60

Cost per 1,000 ft. b.m. = \$6.60 ÷ 2 = \$3.30

Cost for 226,000 ft. b.m. = \$3.30 × 226 = \$745.80

NOTE: As the time required for loading and unloading is large when compared with the travel time, the costs would be reduced by increasing the number of men in the gang, it being assumed that the men would not interfere with each other in their work.

Illustrative Estimate.—A certain contractor has a quantity of face brick to unload from freight cars, transport 2 miles to the job, and stack at the job. He has one truck available which can haul 1000 brick per load, and can maintain an average speed of 20 m.p.h. with an allowance for short delays. The cost of this truck with driver is $2.25 per hour, and wages of an ordinary laborer are $0.50 per hour. The overhead charge is $0.10 per hour per laborer and $0.25 per hour for the truck. Brick tongs will be used for loading and unloading. The laborers will ride from freightyard to job and back again with the truck. The driver does not assist in loading or unloading. Assume that 1 man will load 600 brick from car to truck per hour or from truck to stack; 2 men, at rate of 1,200 brick per hour; 3 men, at rate of 1,700 brick per hour; 4 men, at the rate of 2,100 brick per hour; and 5 men, at the rate of 2,400 brick per hour. More than two men will interfere with each other to some extent. What size of gang would be the most economical, and what should be the estimated cost per 1000 brick?

Solution.

One-man gang:

One round trip will care for 1000 brick.

Total truck cost = $2.25 + 0.25 = $2.50 per hour, including overhead.

Total wage per man per hour = $0.50 + 0.10 = $0.60, including overhead.

Load = 1.67 hr. Unload = 1.67 hr. Travel 4 miles = 0.20 hr.

Total = 3.53 hr. for 1 trip.

Cost per 1000 brick = 3.53($2.50 + $0.60) = $10.95.

Two-man gang:

Load = 0.833 hr. Unload = 0.833 hr. Travel = 0.20 hr.

Total = 1.87 hr. for 1 trip.

Cost per 1000 brick = 1.87($2.50 + 2 × $0.60) = $6.93.

Three-man gang:

Load = 0.59 hr. Unload = 0.59 hr. Travel = 0.20 hr.

Total = 1.38 hr. for 1 trip.

Cost per 1000 brick = 1.38($2.50 + 3 × $0.60) = $5.93.

Four-man gang:

Load = 0.476 hr. Unload = 0.476 hr. Travel = 0.20 hr.

Total = 1.15 hr. for 1 trip.

Cost per 1000 brick = 1.15($2.50 + 4 × $0.60) = $5.63.

Five-man gang:

Load = 0.417 hr. Unload = 0.417 hr. Travel = 0.20 hr.

Total = 1.034 hr. for 1 trip.

Cost per 1000 brick = 1.034($2.50 + 5 × $0.60) = $5.70.

According to the data given, the truck and driver with the 4-man gang would be the most economical combination in regard to cost.

Illustrative Estimate.—A certain contractor has a large quantity of cement in sacks to unload from freight cars, transport 3 miles to the job, and pile in a cement house. He has 3 trucks available for this purpose, each truck capable of hauling 60 sacks of cement per load. Each truck can maintain an average speed of 20 m.p.h. when traveling, with allowance for

small delays. Cost per hour (including overhead) of a truck and driver is estimated at \$3. Ordinary labor can be secured at a cost (including overhead) of \$0.55 per hour. It takes 1 man 1 min. to carry a sack of cement from a freight car and pile it in a truck. It takes 1 man 1¼ min. to carry a sack of cement from the truck and pile it in the cement shed. One gang will be used for loading and another gang for unloading. One man in each gang will be the straw boss of that gang and his wage is \$0.65 per hour, including overhead. The straw bosses will work with the men. The truck drivers will not help load or unload the trucks. Determine the most economical size of each gang, and compute the cost of handling the cement per sack.

Solution: This estimate is similar to the preceding estimate in that varying sizes of gangs may be tried, but it differs in that two gangs will be needed and the gangs will not travel on trucks. It may be that the gangs will be idle some of the time. No doubt it would be advisable to keep trucks busy all the time, even if one or both gangs are idle a little of the time. Loading times should equal unloading times (approximately) so as to reduce the amount of time that any gang is idle. The unloading gang should be about 1.25 as large as the loading gang, to keep these times about equal.

Try 3 men loading and 4 men unloading:

$$\text{Time to load a truck} = \frac{60 \times 1}{3} = 20 \text{ min.}$$

Time to travel 3 miles and return $= 9 + 9 = 18$ min.
Time for one trip $= 48$ min. if no delays
However, it takes 15 min. to load (or unload) one truck; hence, 4 trucks could be loaded per hour if trucks arrived that fast (*i.e.*, every 15 min.). Trucks will arrive every $48 \div 3$, or 16, min.; hence, each gang will have a 1-min. wait between trucks. There will be no truck delays.

Truck cost per trip $= \$3 \times {}^{48}\!/_{60} = \$2.40$

Cost of loading $= (\$0.65 + 3 \times \$0.55) \times \dfrac{15 + 1}{60} = \$0.613$

Cost of unloading $= (\$0.65 + 4 \times \$0.55) \times \dfrac{15 + 1}{60} = \$0.76$

Total cost of one trip $= \$2.40 + \$0.613 + \$0.76 = \$3.773$
Cost per sack $= \$3.773 \div 60 = \$0.0629$

Here the gangs are balanced, and each gang gets a minute's rest between trucks. A good arrangement.

Try 5 men loading and 6 men unloading:

Time to load one truck $= \dfrac{60 \times 1}{5} = 12$ min.

Time to unload one truck $= \dfrac{60 \times 1.25}{6} = 12.5$ min.

Time to travel 3 miles and return $= 18$ min.
Total time for one trip $= 42.5$ min. if no delays

Trucks will arrive every $42.5 \div 3 = 14.2$ min., so that loading gang will have a 2.2-min. wait between trucks and the unloading gang a 1.7-min. wait.

Truck cost per trip $= \$3 \times \dfrac{42.5}{60} = \$2.125$

Cost of loading $= (\$0.65 + 4 \times \$0.55) \times \dfrac{12 + 2.2}{60} = \$0.675$

Cost of unloading $= (\$0.65 + 5 \times \$0.55) \times \dfrac{12.5 + 1.7}{60} = \$0.805$

Total cost per trip $= \$3.605$ (say $\$3.60$)
Cost per sack $= \$3.60 \div 60 = \$0.0600$

Try 6 men loading and 8 men unloading:

By following the same process of analysis, the total time per trip is found to be 37.4 min., the cost per trip to be \$3.47, and the cost per sack to be \$0.0578.

Try 7 men loading and 9 men unloading:

By following the same process of analysis, the time per trip is found to be 34.9 min., the cost per trip to be \$3.49, and the cost per sack to be \$0.0582.

Try 8 men loading and 10 men unloading:

By following the same process of analysis, the time per trip is found to be 33 min., the cost per trip to be \$3.50, and the cost per sack to be \$0.0583. Another example of balanced gangs. Each gang has an idle period of 3.5 min. between trucks.

Try 9 men loading and 11 men unloading:

By following the same process of analysis, the time per trip is found to be 31.5 min., the cost per trip to be \$3.55, and the cost per sack to be \$0.592.

shovelers for the 1 cu. yd. shovel. Wage of shovelers, including all overhead, is $0.55 per hour per man.

Estimate the costs of supplying gravel by each of these methods, assuming average truck speeds of 30 m.p.h. for the 2.5 cu. yd. trucks and 28 m.p.h. for the 4 cu. yd. trucks.

Solution: 1. Estimated cost of gravel from material supply company, $0.95 (per cubic yard) × 7,800 (cubic yard) = $7,410.

2. Estimated cost of gravel purchased from pit and using rented equipment from Company *A*:

Assume trucks to average 30 m.p.h.

Time for one trip = 3 min. (get in position and load) + 16 min. (travel loaded) + 1 min. (dump) + 16 min. (return) + 4 min. (delays) = 40 min. = 0.667 hr.

Then 12 ÷ 0.667 gives 18 trucks per hour at shovel.

Shovel could load 20 trucks per hour if they were available.

Gravel loaded per hour = 18 × 2.5 = 45 cu. yd.

Hours required for 7,800 cu. yd. = 7,800 ÷ 45 = 174 hr.

Gravel cost	= $0.125 × 7,800 cu. yd.	= $ 975
Shovel cost	= $70 + $4.50 × 174 hr.	= 853
Truck cost	= $2 × 12 trucks × 174 hr.	= 4,176
Superintendent and shovelers	= ($2 + 2 × $0.55) × 174 hr.	= 539
Total cost		= $6,543

Cost per cubic yard = $6,543 ÷ 7,800 = $0.839 (say $0.84)

The use of 13 trucks instead of 12 would reduce costs a little.

3. Estimated cost of gravel purchased from the pit and using rented equipment from Company *B*:

Assume trucks to average 28 m.p.h.

Time for one trip = 3 min. (get in position and load) + 17 min. (travel loaded) + 1 min. (dump) + 17 min. (return) + 4 min. (delays) = 42 min. = 0.70 hr.

Then 10 ÷ 0.70 gives 14.3 trucks per hour at shovel.

Shovel could load 20 trucks per hour if they were available.

Gravel loaded per hour = 14.3 × 4 = 57.2 cu. yd.

Hours required for 7,800 cu. yd. = 7,800 ÷ 57.2 = 137 hr.

Gravel cost	= $0.125 × 7,800	= $ 975
Shovel cost	= $90 + $6 × 137	= 912
Truck cost	= $3 × 10 × 137	= 4,110
Superintendent and 3 shovelers	= ($2 + 3 × $0.55)137	= 500
Total cost		= $6,497

Cost per cubic yard = $6,497 ÷ 7,800 = $0.833

It would be cheaper for the highway contractor to rent equipment from either Company *A* or Company *B* and to haul the gravel, instead of buying the gravel delivered at the job from the material supply company.

The total cost (and the cost per cubic yard) could be reduced if enough 4 cu. yd. trucks could be rented to keep the 1 cu. yd. shovel working at

capacity. The total number of trucks required would be 20×0.70, or 14. These 14 trucks would permit the shovel to load 20×4, or 80, cu. yd. of gravel per hour.

Then the hours required for 7,800 cu. yd. would be $7{,}800 \div 80 = 97.5$ hr. (say 98)

Gravel cost	$= \$0.125 \times 7{,}800$	$= \$\ \ 975$
Shovel cost	$= \$90 + \$6 \times 98$	$= \ \ 678$
Truck cost	$= \$3 \times 14 \times 98$	$= \ 4{,}116$
Superintendent and 3 shovelers	$= (\$2 + 3 \times \$0.55)98$	$= \ \ 358$
Total cost		$= \$6{,}127$ (a saving of \$370)

Cost per cubic yard $= \$6{,}127 \div 7{,}800 = \$0.786$

Consequently, it would pay the contractor to rent 4 additional 4 cu. yd. trucks at the same hourly rate. If these 4 additional trucks could be so rented, the cheapest method would be to purchase the gravel at the pit and then load and haul the gravel to the job by means of the equipment rented from Company *B* and the 4 additional trucks.

CHAPTER III

EXCAVATION

1. Excavation.—Excavation deals primarily with the handling and transportation of the soil, though in a complete excavation job many other items may need to be included. For example, the excavation of a basement for a large building may include such items as clearing the site, removing old buildings, loosening and removing soil, breaking and removing rock, filling and grading, bracing and shoring, sheet piling, pumping water, digging trenches, and protecting adjacent property.

The costs of excavation, and the estimates of these costs, depend upon several things such as class of excavation (special and general); quantity or amount of excavation; kind of soil; disposal of excavated materials; other items of work required in connection with the particular job; methods used for loosening and digging, transporting, and disposing of the materials; and delays caused by weather, machinery breakdowns, labor troubles, etc.

2. Classes of Excavation.—Excavation may be divided into two classes:

1. General excavation, such as excavation for a large basement or for a large cut for a railway or highway. General excavation may be done by almost any method such as teams and scrapers, or power shovels and trucks, for example.

2. Special excavation, such as digging trenches or footing holes for foundations. Handwork is nearly always required for special excavation.

3. Kinds of Soil.—Soil may be divided into five kinds according to the difficulty experienced in excavating it. Soils vary greatly in character, and no two are exactly alike.

1. Light soil. Requires no loosening. Can be shoveled easily. Sand is an example.

2. Medium or ordinary soil. Easily loosened by pick and plow. Preliminary loosening is rarely required when power

TABLE 3-1.—APPROXIMATE ANGLES OF REPOSE

Material	Angle with horizontal, degrees		
	Dry	Moist	Wet
Sand	20–35	30–45	20–40
Earth	20–45	25–45	25–30
Gravel	30–50		
Gravel, sand, and clay	20–35		

4. Computing Quantities.—The unit used when computing quantities of excavation is usually the *cubic yard.* The cubic foot is sometimes used when the quantity considered is quite small.

In the take-off, each item of general and special excavation should be listed separately, with dimensions, quantities, and the kind of soil. It should be noted if the earth is firm and will retain its vertical position without side supports or bracing, or if the earth wall will require sheathing or bracing. Sometimes when excavating with power equipment it is more economical to omit the sheathing or bracing and to slope the banks.

When computing quantities for excavation, the estimator must be careful to include the dimensions from outside to outside of all footings and forms, and from the top of the grade to the lowest point of excavation. If the surface of the ground is sloping or uneven, the horizontal projection may be divided into a number of convenient squares and rectangles, and the average height of each section estimated.

5. Methods Used for Excavating.—There are several methods that may be used in excavating soil. For example, the soil may be loosened by picks, team and plow, tractor and plow, or blasting. The material may be dug by hand shovels, team and scraper, tractor and scraper, or by a power excavator such as a shovel or dragline scraper. The transporting may be done by wheelbarrows, scrapers, dump wagons, autotrucks, crawler wagons, or railway dump cars. The material may be disposed of by merely dumping, or by dumping and leveling by hand, scrapers, graders, or bulldozers, as the case may be. A typical excavating job will usually require loosening and digging, transportation, and disposal.

6. Factors Affecting Excavation Costs.—The estimator must remember to include every cost item. No item should be omitted. It is not so important as to what part of the cost classification any item is placed under, provided that the estimator knows and understands the classification used, and classifies the same item in the same manner each time. When not so classified, the exception should be noted.

When estimating excavation costs, several items must be considered, some of which may not always be apparent. For example, when estimating trenches, the following questions must be answered:

Will the sides of the trench remain vertical, or will they cave

Will a power excavator (shovel or dragline excavator) be used?

What is its capacity and cost?

Will scrapers be needed? If so, how many?

Will a team (or tractor) and a plow be required?

If transportation is required, what vehicles will be used?

If dump wagons are to be used, how many are needed?

If trucks are to be used, how many are required and of what capacity?

In what manner will the excavated earth be disposed of?

Will extra laborers be required for any purpose? If so, how many?

What are the hourly costs of the various items of equipment which are to be used?

The fundamental law for securing low costs is "to select, arrange, and use the men and equipment so that the total cost of the job will be a minimum." In general, all men and machines should be worked at full capacity during working hours. Delays should be kept at a minimum. If some of the men or machines must be idle at times, the most expensive should be kept as busy as possible. For example, in an excavation job the power shovel may be the most expensive piece of equipment, and it should be kept busy during all the working hours. Sufficient trucks should be provided to keep the shovel busy, even if a truck should have to wait a little occasionally. Likewise, if the use of a few shovelers will speed up the work of the shovel at the excavation, maintain ramps in good order, or reduce the time required by the trucks at the dumping ground, these shovelers should be provided even if they may be idle a few minutes out of every hour on the average. Sometimes more than one shift may be used to speed up production and reduce overhead.

7. Methods of Estimating Excavation Costs.—There are two ways of estimating excavating costs. One way is to consider each class of excavation and each kind of soil and prepare separate estimates (handling, transportation, and overhead) for each. The other way is to estimate the total cost of handling of all excavation, the total cost of transportation of all excavation, and the total overhead on all excavation. The first way is usually preferred.

There are also two methods of preparing cost estimates for any one kind or class of excavation. One method is to obtain the total costs of each of the four main items (the total-cost method),

and then find the sum. Unit costs are found by dividing the total costs by the number of cubic yards of excavation. The other method (the unit-cost method) is to estimate the cost per cubic yard of handling, transporting, overhead, profit, and total, and then get the cost of the job by multiplying the unit cost by the number of cubic yards. Either method is satisfactory if no costs are omitted.

8. Preparation of Excavation-cost Estimates.—After the take-off has been completed showing all kinds and quantities of excavation, and after the methods and equipment to be used have been decided upon, a cost estimate may be prepared. This estimate may be divided as follows:

overhead is based on labor costs of handling and transporting the material, the percentage may vary from about 15 to 40.

Profit.—If the excavation job is a separate job, some allowance, say 5 to 12 per cent, should be allowed for profit.

9. Loosening Soil.—Table 3-2 gives the approximate times required for loosening various soils with different equipment. Light soil requires no preliminary loosening.

TABLE 3-2.—LOOSENING SOIL (APPROXIMATE)

Method	Cu. yd. per hour			Hours per cu. yd.		
	Medium soil	Heavy soil	Hard pan	Medium soil	Heavy soil	Hard pan
Man and pick..	2– 4	1– 3	0.5–1.5	0.25–0.50	0.33–1.00	0.67–2.00
Team and plow.	25– 50	15–30	....	0.02–0.04	0.03–0.07	
Tractor and one plow.........	40– 70	25–50	5–20	0.01–0.03	0.02–0.04	0.05–0.20
Tractor and 2-gang plow....	50–100	40–70	....	0.01–0.02	0.01–0.03	

The cost of loosening rock by drilling and blasting will depend upon the kind of rock, ease of drilling, use of hand or machine drills, skill and wages of workmen, and amount and cost of explosives used. The general subject of rock excavation will be considered in a later article (see Art. 34 on Rock Excavation).

10. Digging Soil by Hand Labor.—Digging soil by hand shoveling is perhaps the oldest and simplest method. The amount of work done per man per hour varies greatly with the skill of the laborer, his inclination to work, the condition of the soil (dry or wet), the kind of the soil, the height or lift, and the working conditions on the job. A further discussion on excavation by hand shoveling is given in the articles on Backfilling, Trenching with Hand Labor, and Excavation by Hand.

Table 3-3 gives the approximate outputs for shoveling loosened material into wagons or trucks. An increase in the total lift up to about 6 ft. will decrease the hourly output about 5 to 10 per cent for each foot of increase. Likewise, a decrease in the total lift will increase the hourly output about 5 to 10 per cent per foot.

Table 3-4 gives the approximate outputs per labor-hour for shoveling in excavation, including some loosening with a pick,

TABLE 3-3.—SHOVELING LOOSENED SOIL INTO WAGONS OR TRUCKS
Total lift about 4 ft.

Soil	Cu. yd. per labor-hr.	Hr. per cu. yd.
Light, from ground	1.20–2.50	0.40–0.85
Medium, from ground	1.00–2.00	0.50–1.00
Hard or heavy, from ground	0.80–1.50	0.65–1.25
Hard pan, from ground	0.70–1.25	0.80–1.40
Light, from excavation	1.10–2.30	0.45–0.90
Medium, from excavation	0.90–1.80	0.55–1.10
Hard or heavy, from excavation	0.70–1.35	0.75–1.45
Hard pan, from excavation	0.60–1.10	0.90–1.65

and for a total lift not over 6 ft. In general, the output increases as the total lift decreases, and this must be considered when selecting values from the table.

TABLE 3-4.—SHOVELING SOIL INTO WAGONS AND TRUCKS FROM EXCAVATION, INCLUDING SOME LOOSENING WITH PICKS
Total lift not over 6 ft.

Soil	Excavation	Cu. yd. per labor-hr.	Hours per cu. yd.
Light	General, dry	1.00–1.75	0.55–1.00
	General, wet	0.70–1.30	0.75–1.45
	Special, dry	0.90–1.50	0.65–1.10
Medium	General, dry	0.80–1.40	0.70–1.25
	General, wet	0.55–1.00	1.00–1.80
	Special, dry	0.70–1.20	0.85–1.45
Hard or heavy	General, dry	0.60–1.15	0.85–1.70
	General, wet	0.35–0.65	1.55–2.85
	Special, dry	0.45–0.80	1.25–2.25
Hard pan	General, dry	0.50–1.00	1.00–2.00
	General, wet	0.25–0.50	2.00–4.00
	Special, dry	0.35–0.65	1.55–2.85

When the excavation is more than 5 ft. in depth, the soil must be rehandled by extra men using stages or platforms. For every two or three diggers, an extra man is required for each rehandling

or for each stage. Note that the amount of excavation per labor-hour will be reduced as extra men are used to reshovel the soil.

Diagram 3-1 (page 546) may be used for estimating the costs of hand shoveling when the labor wage is known and the labor output may be reasonably assumed.

11. Digging Soil with Power Equipment.—Some kind of power equipment is usually used for digging the soil except on very small jobs or on special excavation. Types of equipment commonly used are power shovels, dragline excavators, tower excavators, cranes and derricks with booms and buckets, trenching machines, tractor-drawn scrapers, elevating graders, and various types of special equipment. For detailed descriptions of different types of power equipment, the reader is referred to books on construction equipment and to the catalogues of the manufacturers. The discussion given in the preceding chapter in Art. 12 on Unloading and Loading Materials with Power Equipment may be reviewed at this time.

The output of a power excavator, such as a power shovel or dragline excavator, depends upon the size of the bucket, dipper, drag bucket or scraper; the number of loads handled per minute or per hour; the kind of soil, weather, and job conditions; amount of moving required; delays of various kinds; and the skill of the operator.

A power excavator should average one to three bucket, dipper, or scraper loads per minute during the working day. The number of loads per minute will usually vary inversely with the amount of the load, the reach or length of boom, and the distance through which the load is swung or carried. A larger machine usually operates slower than a smaller one, and more time is required to operate a long boom than a short one.

Each type of power excavator has its advantages and disadvantages. Some types of machines work more efficiently on some kinds of jobs than on others. For example, a steam shovel or dragline scraper may be the most suitable for the excavation of a basement for a large building, a derrick or crane with a bucket for deep excavation, and an elevating grader for a cut on a new highway.

Table 3-5 gives the approximate capacities of power excavators such as shovels and dragline scrapers.

TABLE 3-5.—APPROXIMATE OUTPUTS OF POWER EXCAVATORS USED FOR DIGGING SOIL

Bucket dipper, or scraper capacity, cu. yd.	Machine with a short reach*		Machine with a longer reach†	
	Cu. yd. per hr.	Hr. per 1,000 cu. yd.	Cu. yd. per hr.	Hr. per 1,000 cu. yd.
½	30–100	10.0–33.3	25– 75	13.3–40.0
¾	45–130	7.7–22.2	40–100	10.0–25.0
1	60–160	6.3–16.7	55–125	8.0–18.2
1¼	75–190	5.3–13.3	70–150	6.7–14.3
1½	90–120	4.6–11.1	80–175	5.7–12.5
1¾	105–245	4.1– 9.5	90–200	5.0–11.1
2	120–270	3.7– 8.3	100–220	4.6–10.0
2½	145–320	3.1– 6.9	120–260	3.9– 8.3
3	170–370	2.7– 5.9	140–300	3.3– 7.1
3½	190–420	2.4– 5.3	160–330	3.0– 6.3
4	210–460	2.2– 4.8	175–350	2.9– 5.7
5	250–550	1.8– 4.0		
6	285–630	1.6– 3.5		

* Such as a power shovel with short boom and dipper.
† Such as a dragline scraper with a long boom, or a crane with a long boom and bucket.

When trucks or wagons are used with a power excavator, the capacity of a truck or wagon should be equal to one or more times the load handled at one time by the excavator (dipper, bucket, or scraper load). There should be a sufficient number of trucks or wagons available to keep the excavator busy during all working hours.

The cost of power excavators includes such items as first cost, interest, depreciation, rents (if rented), general overhaul and repairs, storage, transportation to and from the job, lubrication, fuel or power, insurance, maintenance and operating repairs, labor of operators and other workers, and overhead. See Appendixes B and C for equipment costs.

There are several ways of computing costs of power equipment. Almost any way is satisfactory provided that it is understood and that all cost items are included. Perhaps the best way is to compute the hourly cost of operation because most costs vary with the time the equipment is in use. This hourly cost should include allowances for all such items as are mentioned in the preceding paragraph. When computing hourly costs due to

items other than operation, the probable number of hours that the equipment will be working must be estimated.

12. Backfilling.—Backfilling may be done by hand shoveling, by scrapers, or by bulldozers (tractors with a scraper fastened to the front). The time required for backfilling by hand will depend on the ease with which the material can be shoveled, and on the tamping or compacting required.

Table 3-6 gives approximate rates of work.

TABLE 3-6.—BACKFILLING WITH HAND LABOR

Soil	Shovel only		Shovel and tamp	
	Cu. yd. per hr.	Hr. per cu. yd.	Cu. yd. per hr.	Hr. per cu. yd.
Light	1.5–3.0	0.35–0.65	0.8–2.2	0.45–1.25
Medium	1.3–2.5	0.40–0.75	0.7–1.8	0.55–1.45
Hard or heavy	1.0–2.0	0.50–1.00	0.6–1.5	0.65–1.65

Tamping time is assumed to vary from about one-fourth to one-half of the total time.

When the backfill material must be wheeled, the time required will be increased proportionately.

The amount of backfilling accomplished by a bulldozer and operator will vary with the material, the size of the machine, and the skill of the operator. The quantity of earth handled per hour may vary from about 3 to 30 cu. yd.

13. Spreading Soil.—One man with a shovel should be able to spread and level 1 to 3 cu. yd. per hour of light or medium soil. If the soil must be wheeled, these quantities will be reduced proportionately. A two-horse scraper or grader should be able to spread and level 2 to 8 cu. yd. per hour, and a bulldozer 3 to 30 cu. yd. per hour or more, depending upon the requirements of the particular job.

14. Pumping.—An estimate of the pumping requirements and costs can not be readily made, unless there is some way of determining in advance the probable amount of water that will need to be handled and the distance it must be pumped. If the amount of water is small, one or two hand pumps or a small power pump will answer the purpose, and the cost will not be

TABLE 3-8.—LABOR REQUIRED FOR SHOVELING SOIL IN TRENCHES
Including loosening with picks as required

Soil	Depth of trench, feet					
	3	5	8	10	12	15
	Output, cubic yards per man per hour					
Light.....	1.00–1.80	0.95–1.70	0.85–1.55	0.80–1.45	0.70–1.30	0.65–1.20
Medium..	0.85–1.60	0.80–1.50	0.75–1.40	0.70–1.30	0.60–1.15	0.55–1.05
Heavy....	0.65–1.25	0.62–1.20	0.55–1.05	0.53–1.00	0.45–0.90	0.43–0.85
Hard pan.	0.50–1.00	0.47–0.95	0.43–0.85	0.40–0.80	0.35–0.70	0.33–0.76
	Labor-hours per cubic yard					
Light.....	0.55–1.00	0.60–1.05	0.65–1.15	0.70–1.25	0.75–1.40	0.80–1.50
Medium..	0.65–1.20	0.70–1.25	0.75–1.40	0.80–1.50	0.90–1.70	0.95–1.80
Heavy....	0.80–1.55	0.85–1.65	0.95–1.80	1.00–1.90	1.15–2.20	1.20–2.30
Hard pan.	1.00–2.00	1.05–2.10	1.15–2.35	1.25–2.50	1.40–2.80	1.50–3.00

or calking. Hence, the width required for a 4-in. pipe would be about 4 plus 16, or 20 in., and that for a 30-in. pipe would be about 30 plus 20, or 50 in. When the pipe sections can be joined together on the ground and then lowered into the trench, the required trench width will be less.

Perhaps the simplest way of estimating trenching costs by hand labor is to (1) compute the quantity of each kind of soil in cubic yards, (2) knowing the depth of trench, estimate the hours required for a man to excavate 1 cu. yd. of each kind of soil, (3) knowing the hourly wage, compute the cost per cubic yard for each kind of soil, (5) compute the total cost for each kind of soil, and (6) sum up the costs.

Equipment costs will be the wear on tools (picks, shovels, etc.), their loss, and the expense of transporting them to and from the job. These costs may vary from a few dollars up to $100 or more, depending on the particular job. On some jobs, allowances must be made for bracing and shoring, for pumping, and for stages and platforms for rehandling the soil.

General overhead costs may vary from about 15 to 40 per cent of the labor costs.

Profit may vary from 5 to 15 per cent.

Diagram 3-1 (page 546 may be used to find the labor costs per cubic yard for excavating and backfilling trenches by hand labor when the hourly wages are known and the hourly outputs for the laborers may be reasonably assumed.

17. Illustrative Estimates.—The following two estimates relate to trenching with hand labor.

Illustrative Estimate.—Estimate the cost of excavating and backfilling a trench 240 ft. long, 4.5 ft. deep, and 24 in. (2 ft.) wide. Soil is ordinary loam (medium soil) and is firm enough so that no bracing will be required. Labor rate is $0.83 per hour including overhead. Allow $4 for equipment.

Assume a rate of 0.90 hr. per cubic yard (1.10 cu. yd. per hour) for excavating and 0.45 hr. per cubic yard (2.20 cy. yd. per hour) for backfilling with some tamping (see Tables 3-6 and 3-8).

$$\text{Cubic yards in trench} = \frac{(240)(4.5)(2)}{27} = 80 \text{ cu. yd.}$$

Excavation cost	= $0.83(0.90)80	=	$59.76
Backfill cost	= $0.83(0.45)80	=	29.88
Equipment	=		4.00
Total	=		$93.64
Cost per cubic yard	= $93.64 ÷ 80	=	$ 1.17

By using Diagram 3-1, 0.90 hr. per cubic yard for excavating plus 0.45 hr. per cubic yard for backfill equals 1.35 hr. per cubic yard. At an hourly rate of $0.83, the diagram gives the cost per cubic yard as about $1.12.

Cost of digging and backfill = $1.12 × 80	=	$89.60
Equipment	=	4.00
Total	=	$93.60

Or a unit cost of about $1.17 per cubic yard.

Illustrative Estimate.—Estimate the cost of excavating and backfilling a trench 140 ft. long, 8.5 ft. deep, and 2 ft. wide. Soil is heavy, requiring some loosening with picks. Soil is firm enough so that no bracing is required. Labor rate is $0.76 per hour including overhead. Equipment allowance is $16 for shovels, picks, stages or platforms, and for transporting equipment to and from the job. Backfill requires tamping.

Assume a rate of about 1.40 hr. per cubic yard (0.7 cu. yd. per hour) for digging and 0.60 hr. per cubic yard (1.33 cu. yd. per hour) for backfill (see Tables 3-6 and 3-8).

$$\text{Cubic yards in trench} = \frac{140(8.5)2}{27} = 88.15 \text{ cu. yd.}$$

Cost of excavating	= $0.76(1.40)88.15	=	$ 93.85
Cost of backfill	= $0.76(0.60)88.15	=	40.15
Equipment		=	16.00
Total		=	$150.00

Then total cost of excavation and backfill

$$= (\$0.25 + \$0.22)420 + \$48.00 + \$12.00 + \$5.00 = \$262.00$$

Cost per cubic yard = $0.623

20. Excavation with Hand Labor.—The cost of hand excavation depends in general upon the class of excavation, kind and condition of soil, the hourly wages and hourly output of the shovelers. The work will consist of loosening the soil, digging, and backfilling or spreading. This work has been discussed in Art. 9 on Loosening Soil, Art. 10 on Digging Soil by Hand, Art. 12 on Backfilling, Art. 13 on Spreading, and Art. 16 on Trenching with Hand Labor. Tables 3-2, 3-3, 3-4, and 3-8 may be consulted when estimating the output. Then, when the hourly wage is known, the cost per cubic yard may be found by means of Diagram 3-1 or computed by arithmetic, as desired.

21. Illustrative Estimate.—Estimate the cost of 23 cu. yd. of special excavation and 15 cu. yd. of backfill with tamping of ordinary loam (medium soil). Hand labor is to be used at an hourly wage of $0.83 including overhead. Equipment costs are estimated at $3. This special excavation and backfill are required in the construction of the foundation of a large building.

From Table 3-4, approximately 1.30 labor-hours of shoveling may be assumed per cubic yard of special excavation, and from Table 3-6 about 1.10 hr. per cubic yard may be assumed for backfilling and tamping.

Excavation cost	= $0.83(1.30)23	= $24.85
Backfilling and tamping cost	= $0.83(1.10)15	= 13.70
Equipment cost		= 3.00
Total		= $41.55

From diagram 3-1, the cost per cubic yard for excavation is about $1.08, and the cost per cubic yard for backfilling and tamping is about $0.91.

Excavation cost	= $1.08(23)	= $24.90
Backfill and tamping cost	= $0.91(15)	= 13.65
Equipment cost		= 3.00
Total		= $41.55

22. Excavation with Hand Labor and Wheelbarrows.—The cost of excavating by hand labor and wheelbarrows will depend upon such items as the kind and condition of the soil, the labor output per hour loosening and shoveling, the capacity of the barrows and their loading, the difficulties of wheeling (steepness of incline and roughness of path), the distance wheeled, the weather, the skill of the workmen, and their wages. The output of workmen loosening and shoveling soil has been discussed in

Arts. 9 and 10 and transportation by wheelbarrows in Art. 15 of this chapter. The output with wet soil may be 20 to 40 per cent less than with dry soil.

The rated capacities of wheelbarrows vary from about 2 to 4 cu. ft. with an average of about 3 cu. ft. Because of the expansion of the soil when loosened, the difficulties of wheeling and the inclination of workmen not to load the barrows to capacity, the actual capacity of a barrow will vary from about 1.5 to 3.0 cu. ft. with an average load of about 2 cu. ft. Whenever practical, the path for wheeling should be made smooth so that the barrows may be fully loaded.

The limit of economical haul for wheelbarrows is about 150 ft., though in some cases barrows have been used up to 200 or even 300 ft. However, when the length of haul is over 100 ft., the cost of transporting with wheelbarrows should be compared with the cost of transporting with other vehicles.

The number of barrows and laborers to be used on a job will depend to some extent upon the size of the job, the number of barrows and men available, and the number that can be used without interference with each other. For example, there may be one laborer with each barrow, or there may be more laborers than barrows with the extra laborers being used to help in the loading. The size of gang and the work of the men in the gang should be such that all the men can be kept busy all the time during working hours.

When preparing rough estimates of time (and cost), the time required for one man to load a barrow is usually taken as 3 min. (two men, 1.5 min.; three men, 1 min.), and a man is assumed to travel at a rate of 100 ft. per minute. Time for dumping is very small and may be included either in the loading or traveling time.

However, the total cost of loosening, digging, and moving earth by hand shoveling and wheelbarrows depends upon the time required for one man to loosen, dig, and move 1 cu. yd., and upon the labor, equipment, and overhead costs. Labor wages may vary from about $0.50 to $1.75 per hour, and overhead costs may vary from 15 to 40 per cent of the labor costs. Small tool and barrow costs will not usually be over a few cents an hour per laborer for a pick, shovel, barrow, and runways plus costs of transportation to and from the job. Equipment costs (except transportation) and overhead costs may reasonably be included

with the hourly wage without appreciable error. Transportation of equipment to and from the job may be added as a separate item, or may be included with overhead, when overhead is treated as a separate item, as desired.

For convenience, the data in regard to digging and transporting soil by barrows has been summarized in Table 3-9. Values are based upon 2.0 cu. ft. per load and travel at 100 ft. per minute, and include loosening, transporting, and dumping soil.

The length of haul (50, 100, or 150 ft.) is the length of haul loaded. The trip length will be twice the length of haul.

TABLE 3-9.—EXCAVATION BY HAND LABOR WITH WHEELBARROWS
Average barrow load assumed as 2 cu. ft.

Soil	Loosen and load, min.	Cu. yd. per man per hour			Labor-hours per cu. yd.		
		Haul 50 ft.	Haul 100 ft.	Haul 150 ft.	Haul 50 ft.	Haul 100 ft.	Haul 150 ft.
Light (sand)....	1.5–3.0	1.12–1.80	0.90–1.28	0.75–1.00	0.56–0.89	0.78–1.11	1.00–1.33
Medium (loam).	2.0–4.0	0.90–1.50	0.75–1.12	0.64–0.90	0.67–1.11	0.89–1.33	1.11–1.56
Heavy (clay)....	2.5–5.0	0.75–1.28	0.64–1.00	0.56–0.82	0.78–1.33	1.00–1.56	1.22–1.78
Hard pan.......	3.0–6.0	0.64–1.12	0.56–0.90	0.50–0.75	0.89–1.56	1.11–1.78	1.33–2.00

For other barrow capacities, the outputs will be in proportion. For example, for an average barrow load of 1.5 cu. ft., the cubic yards per man per hour will be 1.5 ÷ 2.0, or 0.75 of those given in the table, and the labor-hours required per cubic yard will be 2.0 ÷ 1.5, or 1.33 times the labor-hours given in the table.

Other tables may be prepared for other barrow capacities and loading and wheeling times.

Diagram 3-1 gives the cost per cubic yard of digging and wheeling soil in barrows when the hourly wage is known and the hours required per cubic yard of excavation (digging and wheeling) may be reasonably assumed (as in Table 3-9).

23. Illustrative Estimate.—Estimate the cost of excavating 137 cu. yd. of loam and 43 cu. yd. of clay. Soil will be dug by hand and wheeled in barrows an average distance of 75 ft. Wage of laborer is $0.94 per hour, including all overhead and equipment costs except equipment transportation (which may be taken as $8). Weather is good, and soil is fairly dry.

From Table 3-9, it may be assumed that about 1.00 hr. will be required to dig and wheel 1 cu. yd. of loam and about 1.20 hr. per cubic yard for clay with barrow loads averaging 2 cu. ft.

The time required for a trip will be the sum of times required for loading, traveling loaded, dumping, returning empty, getting into position, and delays. The number of wagon loads per hour will depend upon the number of men in the loading gang and their output, on the assumption that enough wagons are provided so that there will be no delays. The number of wagons needed may be found by dividing the trip time by the loading time. A good foreman should be on the job to keep men and wagons busy. The foreman should give most of his time to supervising the work and should not plan on doing physical labor except in emergencies or when the loading gang is small, say about four men or less. When the size of the job permits, more than one loading gang may be used to save time. In some instances, gangs of different sizes and varying numbers of wagons should be considered in order to find the most economical arrangement.

When preparing an estimate, the following procedure may be used:

1. Compute number of cubic yards of each class and kind of soil to be excavated.
2. Determine number of men in one loading gang.
3. Estimate time required for loading one wagon.
4. Decide on number of gangs, if more than one gang is to be used.
5. Estimate time required for a round trip by a wagon.
6. Estimate number of wagons required for each loading gang. This is equal to trip time divided by loading time. If the answer is fractional, the size of the loading gang or the rate of work or both should be varied so that the answer is not fractional, because a fractional part of a wagon cannot be supplied.
7. Estimate the total number of wagons required by all loading gangs.
8. Allow for loosening soil (team, driver, plow, and helper).
9. Allow for spreading soil at the dump.
10. Compute total hourly cost of entire crew, including overhead and profit (if these items are to be cared for).
11. Compute hours required for an output of 1 cu. yd. or compute hourly output of crew in cubic yards. Cubic yards per hour equals the wagons loaded per hour times the cubic yards in one load.
12. Compute unit cost per cubic yard (itemized as desired).

11. Compute hourly output of crew in cubic yards (or compute time required per cubic yard). The cubic yards per hour will equal the average truck load times the number of trucks loaded per hour.

12. Compute cost per cubic yard of excavation. This cost may be itemized if desired.

13. Compute total cost of excavation. This cost may be itemized if desired.

Diagram 3-4 may be used for finding the cost per cubic yard of excavation after the total hourly cost of the crew and trucks has been computed and the hourly output (or time per cubic yard) has been reasonably assumed.

27. Illustrative Estimate.—Estimate the cost of excavating the basement described in the illustrative estimate in the preceding article, assuming the same wages for shovelers and foremen and using auto dump trucks of 2.5 cu. yd. rated capacity at $4 per hour instead of dump wagons, and a small tractor and plow at $2 per hour instead of a team and plow. Assume truck speed as 15 min. per hour for the 0.75-mile haul.

Total yardage = 90 × 50 × 5.1 ÷ 27 = 850 yd.

A loading crew of 9 shovelers will be assumed.

Time to load one truck, on the assumption that one man requires 0.85 hr. to shovel 1 cu. yd. and that the average truck load will be 80 per cent of rated capacity or 2 cu. yd., will be 2 × 0.85 ÷ 9, or 0.19 hr., or 11 min.

Use 2 crews.

Time for one trip = 1 min. to get in position + 11 min. load + 3 min. travel loaded + 2 min. unload + 3 min. return + 2 min. delay = 22 min. = 0.367 hr.

Trucks required for one gang = 22 ÷ 11 = 2.

For 2 loading gangs, 4 trucks are needed.

The small tractor with driver, helper, and plow will be used for loosening soil.

Hourly cost of crew:

Loosening soil	= $2 (1 tractor) + $0.70 (1 helper)	= $ 2.70
Shoveling	= $1.20 (1 foreman) + $0.70 × 2 × 9 (men)	= 13.80
Leveling at dump	= $0.70 × 2 (men)	= 1.40
Transportation	= $4 × 4 (trucks and drivers)	= 16.00
Subtotal		= $33.90
Overhead	= 15 per cent	= 5.09
Subtotal		= $38.99
Profit	= 8 per cent	= 3.12
Total hourly cost		= $42.11

Output per hour = 2 crews × 2 cu. yd. × 60 ÷ 11 = 21.8 cu. yd. per hour.

Hours per cubic yard = 1 ÷ 21.8 = 0.0458 hr.

Hours per job = 850 × 0.0458 = 39 hr., or 850 ÷ 21.8 = 39 hr.

Item	Cost per Cubic Yard	Cost of 850 Cu. Yd.
Loosening soil. . . .	$0.124	$ 105
Shoveling.	0.633	538
Leveling at dump	0.064	54
Transportation	0.734	624
Overhead. . .	0.234	199
Profit. . .	0.143	122
Total. .	$1.932	$1.642

CHECK: $42.11 per hour × 39 hr. = $1.642

If desired, the cost per cubic yard may be checked with Diagram 3-4. For an hourly cost of $42.11 and 0.0458 hr. required per cubic yard, the diagram gives a cost of about $1.93 a cubic yard. The total cost would be $1.93 × 850 = $1,642.

28. Excavation with Horse-drawn Scrapers.—The cost of excavation with horse-drawn scrapers depends upon such items as kind of soil, condition of soil (dry or wet), scraper load, length of haul, wages of men and teams, overhead, and profit. Loosening will probably be required for heavy soil and hard pan, but not for light and medium soils. Drag scrapers will require a helper for loading, say one helper for every 2 to 10 scrapers, depending on the length of haul. Sometimes a helper is used on the dump, but the dumping is usually done by the driver of a drag scraper. A snatch team is needed when the incline or ramp is steep. Fresno and two-wheel scrapers will require helpers for loading and dumping. The larger sizes of scrapers may require two helpers for loading especially in medium and heavy soils.

For convenience, information previously given in regard to horse-drawn scrapers is repeated here in tabular form. The rate

TABLE 3-10.—HORSE-DRAWN SCRAPERS

Kind of scraper	Capacities, cubic yards		Horses required	Economical haul, feet
	Rated	Job		
Drag or slip.	0.13–0.33	0.10–0.25	2 or 3	50–200
Fresno or buck.	0.25–0.75	0.20–0.60	2–6	100–300
Two-wheel.	0.33–0.67	0.25–0.50	2–4	100–500

of travel is 150 to 225 ft. per minute loaded and 175 to 250 ft. per minute empty. The time required for turning and loading will vary from 0.25 to 0.75 min., and for turning and dumping, from 0.20 to 0.50 min. The scraper capacity, as used on the job, will usually be about 75 or 80 per cent of the rated capacity.

The approximate output of various scrapers is given in Diagrams 3-5 and 3-6 (pages 550 and 551). In computing these outputs, scraper loads were taken at about 80 per cent of the rated capacities, a total time of 1 min. was allowed for turning and loading and for turning and unloading, and the rate of travel was assumed at 200 ft. per minute. Trip length is twice the length of haul.

$$\text{Trip time in minutes} = \frac{\text{haul in feet}}{100} + 1$$

$$\text{Cubic yards per hour} = \frac{60 \times \text{scraper load in cubic yards}}{\text{minutes for trip}}$$

$$\text{Hours per cubic yard} = \frac{\text{minutes per trip}}{60 \times \text{scraper load in cubic yards}}$$

The cost of excavating 1 cu. yd. by team and scraper is equal to the total cost per hour of the team and scraper times the hours required per cubic yard, or it is equal to the hourly cost divided by the output in cubic yards per hour. The total hourly cost of team and scraper includes the proportionate cost of helpers for loading and unloading, the cost of team and plow and helper for loosening soil, the cost of a foreman, equipment, overhead, and profit. The relations among hourly cost, hours required to excavate 1 cu. yd., and costs per cubic yard are shown graphically in Diagram 3-7 (page 552). If desired, a cost diagram could be prepared showing the relations among total cost of crew per hour, total output per hour, and cost per cubic yard.

29. Illustrative Estimate.—Estimate the cost of excavating a basement by teams and scrapers. The total excavation is 213 cu. yd. Soil is ordinary loam. A man and team with scraper or plow costs $1.30 per hour, ordinary helpers $0.70 per hour, foreman $1.10 per hour, overhead 10 per cent of all costs, and profit 7 per cent. Soil is to be spread over back of lot. Average haul will be about 75 ft.

Assume crew to consist of 1 foreman, 1 helper, and 2 teams and drivers with 2 drag scrapers (of about 6 cu. ft. rated capacity each) and 1 plow.

Hourly cost of crew will be $1.10 + $0.70 + $1.30 × 2 = $4.40
Overhead = 10 per cent = 0.44
Profit = 7 per cent of $4.84 = 0.34
Total hourly cost = $5.18

Foreman will help with work. Assume that one team and driver with the helper will spend 20 min. of every hour loosening soil with the plow. Average load of drag scraper will be assumed to be 0.175 cu. yd. (about 80 per cent of rated capacity). From Diagram 3-6, the output of one scraper would be 6 cu. yd. per hour (0.167 hr. per cubic yard). However, as one team will be plowing one-third of the time, the output of the two scrapers will be $6 + \frac{2}{3} \times 6$, or 10 cu. yd. per hour. Hence, the two scrapers will require 0.10 hr. to excavate 1 cu. yd.
Total number of hours required = 213 ÷ 10 = 21.3
Total cost = $5.18 × 21.3 = $110.33
Cost per cubic yard = $110.33 ÷ 213 = $5.18 ÷ 10 = $0.52
Cost per scraper for each hour that a scraper is working =
$5.18 ÷ (1 + ⅔) = $3.11.
Then the cost per cubic yard from Diagram 3-7 (page 552 with 0.167 hr. required per cubic yard, is about $0.52.

30. Excavation with Tractor-drawn Scrapers.—The types of scrapers usually used with tractors are large Fresno or bulk scrapers, rotary Fresno scrapers, and four-wheel scrapers. Sometimes a tractor may pull more than one scraper, say two or three.

The output will depend upon the capacity and number of the scrapers, the speed of the tractor, and the time required for loading, unloading, and turning at each end of the route. The capacity of a single scraper may vary from about 0.50 to 3.0 cu. yd. for the Fresno scraper and from 0.5 to 8 cu. yd. and up for the four-wheel scraper. One tractor can handle one Fresno or one, two, or three four-wheel scrapers, depending on the capacity of the tractor, the size of the scraper, and the working conditions. Many of the hitches of tractors to scrapers are arranged so that the driver of the tractor can operate the scrapers (loading and unloading) from the tractor. The tractors often have as many as four forward speeds and one reverse. The speed may vary from 2 to 3 m.p.h. in low gear up to 12 to 15 m.p.h. or more in high gear. The speeds used will vary with the conditions of the particular job.

About 1 to 3 min. may be allowed for turning and loading and for turning and unloading. The time required for traveling will depend upon the length of the trip (twice the length of haul) and

the average speed. The actual capacity of a scraper on the job may be taken as 75 or 80 per cent of the rated or measured capacity, unless other data are available.

The cost per cubic yard will depend mainly upon the hourly output and the hourly operating cost. The cost of transporting tractors and scrapers to and from the job is usually considered as a separate item. Total operating costs for a tractor, including one operator, may vary from $1.50 to $4 per hour, depending on the size of the tractor and the wages of the operator. The cost of a scraper alone may vary from a few cents an hour for the simpler and smaller types up to about $0.50 per hour or more for the larger and more complicated types.

When preparing an estimate, the steps are about as follows:

1. Compute the cubic yards of each class and kind of soil to be excavated.
2. Determine the number of men and machines in the crew.
3. Compute the hourly operating cost of the entire crew.
4. Allow for cost of loosening soil (if necessary).
5. Allow for transportation of machinery to and from the job.
6. Estimate time required for one complete trip, turn and load, travel loaded, turn and unload, travel empty, and delays.
7. Estimate amount of material (cubic yards) hauled per trip.
8. Compute hours required to excavate 1 cu. yd. (or cubic yards per hour).
9. Compute cost per cubic yard of excavation. This cost may be itemized as desired.
10. Compute total cost of excavation. This cost may be itemized as desired.

There are so many variables involved in an estimate of this kind that it is difficult to prepare usable diagrams. The main variables are cost per hour and output per hour (depending upon capacity of scrapers and time required for a trip).

Diagram 3-8 (page 553) shows the relation between speed in miles per hour, length of loaded haul in feet, and hours required for a complete trip. Three minutes per trip are allowed for loading, unloading, turning at each end of the route, and minor delays. Average speeds, loaded and empty, are assumed to vary from 4 to 20 m.p.h. for hauls up to 5,000 ft.

Diagram 3-9 (page 554) may be used for determining the cost per cubic yard when the cost per trip and the yardage hauled per

trip are known. The cost per trip is equal to the cost per hour multiplied by the hours per trip (as found in Diagram 3-8).

31. Illustrative Estimate.—Estimate the cost of excavating (digging), transporting, and dumping 14,350 cu. yd. of loam. Length of haul averages 1,700 ft. Use 4 tractors, each with 2 four-wheel scrapers of 2.50 cu. yd. rated capacity. Tractor operators can operate scrapers from machine. One bulldozer will be used at the dump to spread soil. On foreman will be required to superintend the operations, and 4 laborers will be supplied for shoveling and miscellaneous work. Foreman's wage is $1.70 per hour: laborer's wage is $0.90 per hour. Bulldozer costs $4.50 per hour with operator. One tractor with two scrapers costs $7.00 per hour with operator. All hourly rates include overhead. Cost of moving machinery to and from the job is estimated at $68. Average speed of tractors when traveling is 10 m.p.h.

Yardage is given as 14,350 cu. yd.

Crew, 1 foreman		=	$ 1.70 per hour
4 laborers	at $0.90	=	3.60
4 tractor outfits	at $7.00	=	28.00
1 bulldozer	at $4.50	=	$ 4.50
Operating cost per hour		=	$37.80

Time for one trip, traveling $= \dfrac{2 \times 1{,}700}{10 \times 5{,}280} = 0.0643$ hr.

Loading, turning, etc. = 3 min. = 0.05 hr.

Total trip time = 0.1143 hr.

Yardage per trip per tractor = 2 × 2.50 × 80 per cent = 4 cu. yd.

For 4 tractors = 4 × 4 = 16 cu. yd. per trip

Hours per cubic yard = 0.1143 ÷ 16 = 0.00715

Hours for the job = 14,350 × 0.00715 = 102.5 hr.

Cost per cubic yard = $37.80 × 0.00715 = $0.270

To this must be added the proportionate cost of moving machinery to and from the job. $68 ÷ 14,350 = $0.005

Total cost per cubic yard = $0.270 + $0.005 = $0.275

Total cost of job (without profit) = $0.275 × 14,350 = $3,950

CHECK: $37.80 × 102.5 + $68 = $3,880 + $68 = $3,948

By using diagrams, from Diagram 3-8, hours for 1 trip = 0.1145, about

Cost of 1 trip (1 tractor and 2 scrapers) $= \dfrac{\$37.80}{4} \times 0.1145 = \$1.082$

From Diagram 3-9, cost per cubic yard (4 cu. yd. per tractor trip) = $0.27

Total cost = $0.27 × 14,350 + $68 = $3,880 + $68 = $3,948

32. Excavation with Power Excavators and Movers.—The power excavators include such machines as power shovels, cranes with buckets, draglines, excavators, tower excavators, and elevating graders. The material may be transported by auto dump trucks or by tractors with crawler wagons. A tractor pulling one or two crawler wagons of four, five, or more cubic yards

capacity each is an economical arrangement when the quantity of earth to be moved is large, the haul comparatively short, and the road difficult. The large quantity handled per trip offsets the slow speed. Auto dump trucks are more economical for long hauls over good highways. Each of the power excavators mentioned has its advantages and disadvantages, which determine its suitability for the particular work.

Excavation with power excavators and movers is a problem in the combined handling and transportation of material such as was discussed in Art. 22 of Chap. II. The items of cost are the same as those mentioned in that article. For economy of operation and of costs, the types of power excavators and movers selected will depend primarily on the characteristics of the job. Enough movers should be available to keep the excavator working full time with no waits either on the part of the excavator or of the movers.

The sizes and capacities of power shovels and dragline excavators are given in Table 3-5 in Art. 11 of this chapter. Elevating graders vary somewhat in size and capacity. Their capacity may range from 70 to 150 cu. yd. per hour. The capacity of a crane and bucket will depend (as in the case of a power shovel) upon the size of the bucket and number of bucket loads handled per minute or per hour. The hourly costs of operating shovels, dragline scrapers, and cranes are approximately the same for machines with the same size of dipper, scraper, or bucket. In general, a power shovel will handle a few more cubic yards of material per hour than a crane or a dragline scraper.

The rated capacities of an auto dump truck vary from one to five or more cubic yards. The actual loaded capacity with loose material will be about 75 or 80 per cent of the rated capacity (see Table 3-7).

Before starting to prepare an estimate, Art 6 on Factors Affecting Excavation Costs and Art. 8 on Preparation of Excavation Cost Estimates should be reviewed. The estimate may be divided into

Handling (labor and equipment)................	$
Transportation (labor and equipment)...........	
Overhead (if not cared for otherwise)............	
Profit (if to be included).......................	
Total....................................	$

The procedure for preparing an estimate is about the same as that outlined in preceding articles.

1. Compute number of cubic yards of each class and kind of excavation.

2. Select men and machines. The excavator selected will depend upon the quantity of excavation, kind of soil, and other job characteristics. The movers selected will depend on such things as length of haul, condition of road traveled, and kind of material. The number of movers should be just enough to keep the excavator busy.

3. Compute cost of handling (digging and loading and spreading at dump). The cost per cubic yard will depend upon the cost of operating the machine per hour and the number of cubic yards handled per hour by excavator and spreader. Allowance should be made for extra helpers when required.

4. Compute cost of transporting material. This cost per cubic yard will depend upon the hourly operating cost per truck or tractor and the quantity (cubic yards) of soil handled per hour. The quantity handled per hour will depend upon the capacity of the mover and the time required for a complete trip. The trip time will depend on the length of haul, the average traveling speed of the mover, and the time required for getting into position, loading, unloading, and delays.

5. Overhead costs (if not included in either handling and transportation) are usually taken as a percentage of the total costs of handling and transporting the soil. When computing overhead costs, the expense of moving machines to and from the job should be included, unless this item has already been included in the handling or transportation costs.

6. Profit should be included if the job is complete by itself.

7. The total cost and the cost per cubic yard may be itemized as desired.

Diagrams may be used to reduce the computations required. For example, Diagram 3-10 (page 555) may be used for estimating the cost of handling, such as digging and loading soil or of spreading soil at the dump when the hourly operating cost of a machine and crew are known and the output per hour may be reasonably assumed. Diagrams 3-11 and 3-12 (pages 556 and 557) may be used for estimating the transportation costs. Diagram 3-11 shows the time required for one trip for varying hauls and speeds.

The total time required for one trip, with 0.10 hr. (6 min.) allowed for getting in position, loading, dumping, and minor delays, is given by the right-hand scale. The traveling time required is given by the left-hand scale. The total time for one trip equals the traveling time plus the time allowed for loading, dumping, etc. When a truck takes more or less time for loading, dumping, etc., than that allowed, the truck may increase or decrease its speed a little when traveling so that the correct time schedule can be maintained. See Diagram 2-9 for trip times with a time allowance of 0.15 hr. (9 min.) for loading, unloading, and minor delays. Cost of one trip equals cost per hour of mover times hours required for trip (see Diagram 2-10). Diagram 3-12 shows cost per cubic yard of transporting soil. If desired, diagrams like 3-8 and 3-9 may be prepared for estimating the cost of moving earth by tractor-drawn crawler wagons where the haul is short and the cubic yards per trip are large.

Some estimators prefer to consider the entire crew of men and machines as a unit and to compute the hourly cost of the unit and the amount of work done (cubic yards) per hour by the unit. The procedure in preparing an estimate by this method is about as follows:

1. Compute number of cubic yards of each class and kind of excavation.
2. Select machines and crew.
3. Compute hourly operating cost of machines and crew, including excavator, movers, spreaders, helpers, foreman, etc.
4. Compute cubic yards of soil dug, moved, and dumped per hour.
5. Compute hours required for job (total yardage divided by hourly yardage).
6. Compute operating total cost (cost per hour times number of hours).
7. Add costs of overhead (especially moving machines to and from job).
8. Add profit.
9. Sum up for total costs. Then get costs per cubic yard if desired. Or the last five steps may be as follows:

5*a*. Compute operating cost per cubic yard (hourly cost divided by cubic yards per hour).

6a. Compute overhead (including moving machines) costs per cubic yard.

7a. Compute profit per cubic yard.

8a. Total cost per cubic yard is sum of operating, overhead, and profit costs.

9a. Total cost for job equals total cost per cubic yard times number of cubic yards.

Diagram 3-13 (page 558) may be used for finding the cost per cubic yard when the hourly cost of machines (loaders and movers, etc.) and crews is known and the hourly output may be reasonably assumed.

33. Illustrative Estimates.—Two illustrative estimates follow on excavation with power equipment and movers.

Illustrative Estimate.—Estimate the cost of excavating a basement for a store building. The basement is 90 by 50 ft. in size and averages 5.1 ft. in depth. The soil is ordinary dry loam. Workmen are available at \$0.70 per hour, a superintendent at \$2 per hour, ½ cu. yd. shovel at \$5 per hour, 2.5 cu. yd. rated capacity autotrucks at \$4 per hour, one bulldozer at \$4 per hour. Length of haul from basement to dump is 0.75 mile. Truck speed is 15 m.p.h. for the haul. General overhead (including cost of moving shovel) is to be assumed as 9 per cent of all other costs, and profit is to be figured at 8 per cent.

Cubic yards = 90 × 50 × 5.1 ÷ 27 = 850 cu. yd.

Time allowed for loading, dumping, etc. = 6 min. = 0.10 hr.

Time for one trip = 0.10 hr. traveling + 0.10 hr. load and dump = 0.20 hr. (12 min.)

Net capacity of truck = 80 per cent of 2.5, or 2 cu. yd.

Assume shovel to load one truck every 2.4 min. (0.04 hr.), or 25 trucks per hour.

Number of trucks = trip time ÷ loading time = 0.20 ÷ 0.04 = 5 trucks.

Other crew members are 1 superintendent and 2 laborers at basement and 1 bulldozer with operator at dump.

Yardage handled per hour = 25 trucks × 2 cu. yd. = 50 cu. yd.

Hours required for excavation = 850 ÷ 50 = 17 hr.

Handling crew cost per hour, 1 superintendent	=	\$ 2.00
2 laborers at \$0.70	=	1.40
Shovel	=	5.00
Bulldozer	=	4.00
Total	=	\$12.40 per hour
Transporting crew, 5 trucks	=	\$20.00 per hour
Overhead = 20 per cent of \$32.40	=	6.48 per hour
Profit = 8 per cent of \$38.88	=	3.12 per hour
Total hourly cost	=	\$42.00 per hour

The costs may be itemized as follows:

	Per Hour	Per Cubic Yard	Total
Handling....................	\$12.40	\$0.248	\$211
Transporting................	20.00	0.400	340
Overhead....................	6.48	0.130	110
Profit......................	3.12	0.062	53
Total.......................	\$42.00	\$0.840	\$714

Diagram 3-13 shows about \$0.84 per cubic yard for an hourly cost of \$42.00.

Diagram 3-10 shows about \$0.17 for digging and loading and \$0.08 for spreading, or a total of \$0.25 per cubic yard for handling.

Diagram 3-11 shows total trip time as 0.2 hr. (12 min.).

Cost per trip = \$4 × 0.20 = \$0.80

Diagram 3-12 shows transporting cost as \$0.40 per cubic yard. In this particular problem, the assumptions made are such that the arithmetical computations are easy.

Diagrams are useful in checking computed costs per cubic yard.

Illustrative Estimate.—Estimate the cost of excavating (digging), transporting, and dumping 14,350 cu. yd. of loam. Length of haul averages 1,700 ft. Use an elevating grader (capacity 160 cu. yd. per hour) and tractors each pulling two 5 cu. yd. crawler wagons. Speed of tractors traveling is 10 m.p.h. Cost of elevating grader is given as \$14 per hour and of each tractor with two crawler wagons is \$5.50 per hour.

Cost of superintendent is \$1.75 and of laborers \$0.90 per hour.

All costs include general overhead except cost of moving machinery to and from the job, estimated at \$103. Actual capacity of crawler wagon taken as 4 cu. yd.

Yardage is given as 14,350 cu. yd.

Time for one trip = 3 min. for loading
2 min. for unloading, turns, and delays
4 min. for traveling 2 × 1,700 ft. at 10 m.p.h.
9 min., or 0.15 hr., for a trip

Tractors and wagons needed = 9 min. per trip ÷ 3 min. load = 3 tractors and 6 wagons

Yardage per hour = 160. Hours required = 14,350 ÷ 160 = 89.7 hr.

Hourly cost:	Superintendent	= \$ 1.75
	Say 3 laborers	= 2.70
	Elevating grader	= 14.00
	Tractors and wagons	= 16.50
	Moving machinery (\$103 ÷ 89.7)	= 1.15
	Total	= \$36.10

Cost per cubic yard = \$36.10 ÷ 160 = \$ 0.225

Total cost = \$0.225 × 14,350, or \$36.10 × 89.7 = \$3,230

By checking on Diagram 3-13, cost per cubic yard is \$0.225 and total cost is \$0.225 × 14,350 = \$3,230.

34. Excavation of Rock.—The excavation of rock is a problem in the handling and transportation of materials. However, the work of excavating rock is somewhat different from that of excavating ordinary soil. Rock may be classed as soft, medium, or hard, according to difficulty of drilling and blasting it.

For computing yardage, measurements are taken of the rock as in its original position and before loosening. The volume will be larger after loosening and breaking; 1 cu. yd. of solid rock may be equal to 1.25 to 1.50 cu. yd. measured loose.

For more complete information in regard to rock excavation, the reader is referred to such texts as "Foundations, and Abutments Footings" by Hool and Kinne; "Standard Construction Methods" by Underwood; "Engineering of Excavation" by Massey; and "Handbook of Rock Excavation" by Gillette.

The *handling* of the rock will include the *loosening*, usually including drilling and blasting, and the breaking of larger pieces into smaller ones; the *loading* of the broken rock into vehicles for transportation; and the *disposal* by dumping or spreading at the end of the transportation route.

The rock may be drilled by hand or machine drills and broken by plugs and feathers or by blasting. Large pieces may be broken into smaller ones by sledges, falling weights, blasting, or by drilling and blasting.

The labor and explosives required for loosening 1 cu. yd. of rock will increase with the hardness of the rock. Open-cut rock excavation usually requires less labor and explosives than tunneling. The rate of drilling rock will vary with the hardness of the rock, size of hole, equipment used, and skill of the workmen. The quantity of dynamite required for blasting 1 cu. yd. of rock will vary from 1 to 2 lb. for soft rock in open cut up to about 8 or 10 lb. for hard rock in tunnels.

The equipment required for loosening rock will include various small tools, hand drills, sledges, machine drills, air compressors, and forges and apparatus needed for sharpening the drills.

The cost of loosening rock will depend upon the labor-hourly wage and output, and the amount and cost of the drilling and blasting materials and equipment needed. The cost of power drills, dynamite, supplies, and plant will vary from about 50 to 100 per cent of the labor costs. The cost of rock excavation in

tunnels will be more than that in open cuts, because the hourly labor output will be less owing to restricted space, inconvenient working conditions, and longer waits and delays.

The broken rock may be loaded into vehicles (barrows, carts, wagons, trucks, cars on rails, etc.) by hand labor or power equipment, depending upon the amount of material and the working conditions. Power equipment such as power shovels should be used when practical. The cost of loading will depend upon the hourly output in cubic yards and the hourly costs of labor and equipment.

When estimating the labor required on smaller jobs, the drilling, blasting, and loading are often considered together. Table 3-11 gives the approximate labor required. However, when preparing estimates for larger jobs, the estimate should be divided into loosening (drilling and blasting) and loading.

TABLE 3-11.—LABOR REQUIRED FOR DRILLING, BLASTING, AND LOADING ROCK

Operation	Cu. yd. per labor-hour			Labor-hours per cu. yd.		
	Soft	Medium	Hard	Soft	Medium	Hard
Hand drill, plug and feathers	0.05–0.09	0.03–0.06	0.02–0.04	11–20	17–33	25–50
Hand drill, blasting	0.06–0.11	0.04–0.08	0.03–0.06	9–17	12–25	17–33
Machine drill, plug and feathers	0.10–0.18	0.08–0.13	0.06–0.10	5–10	8–13	10–17
Machine drill, blasting	0.20–0.35	0.15–0.25	0.12–0.18	3–5	4–7	5–9

Quantities measured are of rock in place in ground.

Diagram 3-14 (page 559) shows the labor costs of loosening (by drilling and blasting) and loading (by hand labor) rock in excavation. The rock is considered as measured in its original position in the ground. From this diagram, the labor costs per cubic yard may be found when the labor-hours per cubic yard and hourly wage are known; or the total cost per cubic yard may be found when the labor-hours per cubic yard and the total cost per labor-hour (labor, equipment, overhead, and profit) are known.

The expense of dumping or spreading, as the case may be, will depend upon the work to be done, whether hand or machine labor is to be used, and their costs. The costs of leveling and spreading broken rock will usually be higher than those for leveling and spreading ordinary soil, as the comparative output per hour will probably be less (see Art. 13 on Spreading Soil).

The *transportation* costs will depend upon the time required for one trip, the load carried per trip, and the cost per hour or per trip. The time lost owing to delays may be quite large if the transportation equipment must wait for drilling and blasting operations. The work should be planned so that the delays will be a minimum. The transportation equipment used may be barrows or carts propelled by men; cars on rails and propelled by men, horses, motor equipment, or small engines; wagons drawn by horses; wagons drawn by tractors; or trucks. The methods used for estimating transportation costs as explained in other articles of this chapter and of Chap. II may be used for estimating transportation costs of rock.

The *overhead* costs of rock excavation will be comparatively large because of the hazards of the occupation, special regulations to be met, and the higher costs of workmen's compensation insurance. Overhead costs may range from 15 to 40 per cent of all costs, or from 20 to 60 per cent of the labor costs.

The percentage allowed for *profit* should be somewhat higher than that for other excavation jobs because of the greater hazards and uncertainties. Profit may range from 10 to 25 per cent of all other estimated costs.

The costs of rock excavation may be summarized as follows: A separate estimate should be prepared for each kind of rock (soft, medium, and hard) and for excavation in open cut and tunneling.

Item	Cost per Cu. Yd.	Total Cost
Handling, labor, and equipment	$	$
Loosening, drilling, and blasting		
Loading		
Dumping, leveling, or spreading		
Transportation		
Overhead		
Profit		
Total	$	$

Factors Affecting Rock-excavation Costs.—When preparing cost estimates for rock excavation, the following items need consideration:

Kind of rock, soft, medium, and hard.

Amount of each kind of rock in cubic yards.

Open-cut excavation or tunneling.

Will bracing or timbering be needed?

Will water have to be cared for?

Loosening method to be used (*i.e.*, machine drilling and blasting?)

Materials and equipment needed for drilling and blasting.

Delays in drilling and blasting.

Loading by hand labor or power equipment.

Length of haul and kind of road for transporting broken rock.

Transportation methods (barrows, trucks, etc.).

Equipment needed for transportation.

Transportation delays, especially those caused by drilling and blasting.

Disposal, dumping, leveling, spreading, etc.

Special rules, regulations, and safety requirements to be complied with.

Overhead expenses to be cared for.

Profit to be charged.

35. Illustrative Estimate.—Estimate the costs of drilling, blasting, and loading into trucks for transportation of 43 cu. yd. of medium rock and 27 cu. yd. of hard rock in open cut. Labor wage is $1.30 per hour. Use machine drills and blasting. Assume cost of drills and blasting to be 55 per cent of labor costs for medium rock and 75 per cent for hard rock. Overhead is 42 per cent of labor costs, and profit is 18 per cent.

Rock yardage, medium = 43 cu. yd., hard = 27 cu. yd.

From Table 3-11, assume 5 labor-hours per cubic yard required for medium rock and 7 labor-hours per cubic yard for hard rock.

Item	Cost per Cubic Yard Medium	Hard
Labor	$ 6.50	$ 9.10
Equipment	3.57	6.82
Overhead	2.73	3.82
Profit	2.30	3.56
Total per cubic yard	$15.10	$23.30

Cost of 43 cu. yd. of medium rock at $15.10 = $ 650

Cost of 27 cu. yd. of hard rock at $23.30 = $ 630

Total cost = $1,280

If desired, the costs per cubic yard may be checked from Diagram 3-14, by using total costs per labor-hour of (\$1.30)(1.00 + 0.55 + 0.42)(1.18), or \$3.02, for medium rock, and of (\$1.30)(1.00 + 0.75 + 0.42)(1.18), of \$3.33 for hard rock. From Diagram 3-14, by using \$3.02 and 5 labor-hours per cubic yard for medium rock, the cost is \$15.10 per cubic yard.
For hard rock, by using \$3.33 and 7 labor-hours per cubic yard, the diagram gives a cost of \$23.30 per cubic yard.

Cost of 43 cu. yd. of medium rock at	\$15.10 =	\$ 650
Cost of 27 cu. yd. of hard rock at	\$23.30 =	630
Total cost	=	\$1,280

CHAPTER IV

PILING AND BRACING

A. GENERAL DISCUSSION

1. Kinds of Piles.—The two types of piles in general use are sheet and bearing piles. Sheet piles are used for bracing in trenches and excavation, retaining walls, and bulkheads. Their main purpose is to retain earth in place or to keep out water or earth as the case may be. Bearing piles are used for supporting loads. The materials commonly used for piles are wood, steel, and concrete.

2. Placing and Driving.—Piles of all kinds may be placed by hand, gin pole, special derrick, special tractor crane, or pile-driver derrick or crane, depending on the size and weight of the piles and the equipment available. Machines should be used for placing large and heavy piles.

Piles may be driven by hand labor and mauls, by drop hammer, by power hammer, or by jetting. Only the smaller and shorter piles can be economically driven by hand.

Drop hammers with pile-driver frames, guides or leads, winches, and engines were used considerably in the past. The drop hammers vary in weight from about 500 to 5,000 lb., and the fall from a few feet up to 20 ft. or so. The weight of hammer used depends upon the length and weight of the piles and the character of the soil. Drop hammers require the use of leads or guides.

Power hammers suspended by means of a boom connected with a derrick or crane are now frequently used for pile driving. The crane may have hanging leads or guides or no leads at all if a templet is used. Very small power hammers may be held and operated by one or two men. The hammers may be driven by steam or compressed air and may be single or double acting. In a single-acting hammer, the ram is raised by steam and allowed to fall by gravity. In the double-acting hammer, steam is used to assist gravity on the fall or downstroke. With a single-acting

hammer, the number of blows per minute may vary from about 50 to 75. With a double-acting hammer, the number of blows per minute may vary from 100 to 300, the smaller sizes being faster. The weight of the ram in a power hammer may vary from about 20 up to 10,000 lb., and the length of stroke from about 16 to 40 in. The total weight of a power hammer may vary from about 100 lb. to 20,000 lb.

The *Engineering News* formula has been long used in connection with pile driving by drop and power hammers. This formula is

$$R = \frac{2Wh}{S + C}$$

where R = resistance of pile (load), tons.
W = weight of ram, tons.
S = set or penetration per blow, inches.
h = fall of ram, feet.
C = a constant.
C = 1.0 for a drop hammer.
C = 0.1 for a power hammer driving piles that are not comparatively heavy.
$C = 0.1P/W$ for a power hammer driving heavy piles.
P = weight of pile, tons.

This formula becomes

For drop hammer,

$$R = \frac{2Wh}{S + 1}$$

For power hammer, light piles,

$$R = \frac{2Wh}{S + 0.1}$$

For power hammer, heavy piles,

$$R = \frac{2Wh}{S + \frac{0.1P}{W}}$$

The formulas will give fairly good results for piles driven in soils that possess high internal friction without cohesion, such as sand, gravel, and permeable fills. The formulas may not give

good results for piles driven in soils possessing cohesion, such as fine-grained silts and soft clays.

Jetting, or a combination of jetting with a light power hammer, may be advantageously used for driving piles into sand, gravel, or soft-packed clay. The jet water, under pressure, loosens the material and carries it to the surface, as well as lubricating the surface of the pile. If possible, two jets should be used, one on each side of the pile. If one jet is used, it should be used first on one side and then on the other. The jet pipes should not be fastened to the pile, but should be kept moving up and down as desired.

Alignment of piles may be secured by fixed leads or guides on the pile-driver derrick, by hanging leads on a crane, by templets (usually of timber), or by other forms of timber frame guides. Leads are not needed when templets are used.

3. Pulling.—Piles may be pulled by hand power with a lever arrangement, by jacks, by a line run through a crane or derrick, or by inverted power hammers. Levers and jacks are suitable for small piles in soft soil, but power equipment is usually required for larger and longer piles and in medium or hard soils. Jetting around a pile often helps in loosening the pile while it is being pulled upon.

4. Other Operations.—Other operations connected with pile driving are protection of the tops when driving, use of followers, splicing and cutting off tops.

Piles should be pointed for ease in driving and protection of the lower ends. Special caps may be used if desired. Metal straps over the lower ends of timber piles are a protection. The top of the pile can be protected from the impact of the hammer by using a cushion of timber, old rope, old belting, etc. The cushion should protect the pile head but not absorb too much of the energy of the blow. A steel ring placed around the top of a timber pile will help to prevent brooming. In many cases, caps of metal are placed over the tops of piles to protect the pile heads from being shattered by the blows of the hammer.

A follower may be used when the pile is to be driven below the guides or below the ground or water surface. It may be a short pile or a cylindrical casting of some type placed on the top of the pile to transmit the force of the blow from the hammer to the pile. A follower protects the top of the pile to some extent.

Splicing of piles is necessary when extra long piles are required or when there is a lack of headroom for driving. The piles may be spliced by placing a metal sleeve over the joint or by bolting fishplates on the sides. Lap joints are rarely satisfactory.

Piles may require cutting off for several reasons. When the top of a timber pile is broomed, the broomed part must be removed. When piles cannot be driven as far as desired, the tops must be cut off to the proper height. Timber may be sawed, steel may be sawed or cut with a flame or torch, and concrete may be cut with a chisel and hammer or a power tool.

5. Factors Affecting Piling Costs.—The more important factors affecting the cost of piling are as follows:

Kind of soil. Piles may be driven more easily in some kinds of soils than in others. Driving is easy in mud, silt, or soft loam. Soils like coarse sand, gravel, and hard pan offer much more resistance to driving.

Cost of piles and waling delivered at the job.

Size and weight of pile. The greater the size and weight of the pile, the more the cost of driving.

Depth driven. The greater the depth, the greater the cost.

Spacing of piles. The spacing often determines the amount of *moving of the pile-driving equipment*.

Method selected. The method chosen for placing and driving the piles should be suitable for the kind of soil encountered, and the kind, size, weight, and length of piles used.

Equipment used. The plant or equipment used should be suitable for the soil encountered and the piles used.

Total operating costs of the equipment.

Amount of pulling to be done.

Amount of other operations (splicing, straightening, cutting off tops, etc.) required.

Skill and wages of foreman and crew.

Special laws and regulations to be complied with.

Overhead and profit.

6. Preparation of Estimates.—The cost estimate for piling is usually divided into materials, labor, plant or equipment, overhead, and profit.

The cost of materials is the cost of the piles and waling delivered at the job. This cost includes the first cost plus the transportation to the job plus all incidental expenses connected with

the first cost and transportation. If the piles are to be pulled, then the cost of transportation from the job to the storage yard must be added. Also if the piles are to be pulled and used again, then the salvage value should be deducted.

The cost of labor will include the wages of superintendents, foremen, inspectors, and all skilled and unskilled labor used on the job.

The cost of the plant will be the proportionate share of the first cost plus interest and depreciation (or rental cost, if rented); cost of transportation to the job; erection costs; operating costs (including fuel, grease, power, minor repairs, and moving); takedown or dismantling costs; costs of transportation from the job; and major repairs. Operating costs may or may not include cost of operator.

Overhead costs include such items as have been previously mentioned in preceding chapters. Overhead costs may be based on labor alone, on labor plus plant, or on labor plus plant plus material as the case may be. The percentages usually allowed for overhead will be comparatively high, say from about 15 to 50 when based on labor alone.

Profit is based on the sum of all other costs, the percentage often ranging from 10 to 25.

Perhaps the best way of estimating piling costs is to

1. Compute all material quantities and costs.
2. Decide on crew, and compute hourly cost of crew.
3. Decide on plant, and compute hourly cost of plant.
4. Estimate member of piles handled per hour (placed, driven, pulled, cut off, etc.) hours required per pile, lineal feet per hour, or square feet of wall surface per hour as desired. Then compute total hours required for the job.
5. Estimate amount of waling handled per hour (placed, removed), and compute hours required.
6. Compute total labor and plant costs.
7. Compute overhead costs.
8. Compute profit.
9. Obtain total cost for the job.

Unit costs per pile, per lineal foot of piling, per square foot of piling surface, per lineal foot of waling, etc., may be computed as desired.

Some estimators prefer to make complete estimates for each class of work such as material costs, placing and driving, cutting off, and pulling for piling; and material costs, placing, and removal costs for waling. Then the estimates for each class of work are summed up to obtain the total estimate.

The estimate may be summarized about as follows:

Item	Unit Cost per Pile or per Square Foot of Wall Surface or per Lineal Foot of Pile	Total Cost
Materials	$	$
Labor		
Plant		
Overhead		
Profit		
Total		

B. SHEET PILING

7. Materials for Sheet Piling.—Wood, steel, and concrete piling may be used. Wooden sheet piling is used up to lengths of about 20 or 30 ft., steel sheet piling up to 40 or 50 ft. or more *as it may be spliced, and concrete sheet piling up to about 100 ft.* Waling, bracing, and shoring materials are usually of wood, though other materials may be used. Wooden waling materials may vary from 2-in. plank up to 12-by-12 timbers.

Wooden sheet piling may cost $30 to $120 per 1,000 ft. b.m. f.o.b. plus transportation to the job. Wooden waling and shoring prices are about the same. The salvage of wooden sheet piling and waling may range from about 40 to 90 per cent. Thicknesses of wooden sheet piling are 2, 3, or 4 in. with widths of 4, 6, 8, 10, or 12 in. Common sizes of wooden sheet piling are 2 by 6, 2 by 8, and 3 by 8. Lengths are usually available up to 20 ft. The piles may have plain edges or may be tongued and grooved. Wakefield sheet piles are made by nailing or bolting three planks together so that the middle plank forms a tongue and groove. These piles may be 5, 8, or 11 in. thick and 6, 8, 10, or 12 in. wide, depending on sizes of plank used.

Diagram 4-1 (page 560) may be used for estimating the cost of wooden sheet piling.

Steel sheet piling costs about \$2 to \$3 per 100 lb. (base price) at the mills plus transportation to the job. Costs at the job may range from about \$3 to \$5 per 100 lb. The salvage of steel sheet piling may range from 70 to 95 per cent of the number used. Steel sheet piling may vary in net width from about 7 to 20 in., about 15 or 16 in. being common. Lengths up to about 50 ft. are usually available. Weights may vary from about 12 to 60 lb. per lineal foot, or from 15 to 40 lb. per square foot of wall. Corrugated sheet steel piling may be obtained in lighter weights. Steel waling and accessories for steel sheet piling may cost \$3 to \$6 per 100 lb. (base price) plus transportation to and from the job.

Diagram 4-2 (page 561) may be used for estimating the cost of steel sheet piling.

Reinforced concrete sheet piling may cost about \$20 to \$50 per cubic yard (say from \$5 to \$13 per 1,000 lb.), plus transportation from casting yard or station to job. Reinforced concrete piling will weigh about 4,000 lb. per cubic yard, or 150 lb. per cubic foot. This piling is usually priced at so much per pile, with dimensions, mix, reinforcement, etc., as specified. Concrete sheet piling is rarely used when it is to be pulled later. Concrete sheet piles are usually rectangular in shape with tongue and groove joints. Grooves may be grouted after driving to improve watertightness. Thickness may vary from about 6 to 12 in. and widths from about 12 to 30 in. Concrete piles may be made in almost any length, the length being limited by the facilities for transporting, handling, and driving. Concrete sheet piling is economical as to cost when it is to be left in place and when the loads to be restrained are comparatively large.

Whenever possible, the sheet piling and bracing should be designed by a competent engineer. Then the amounts and kinds of the materials may be more accurately computed.

8. Labor for Sheet Piling.—The size of the crew used in sheet-piling work may vary from 3 or 4 men with one workman acting as straw boss or foreman up to 10 or 12 men under a foreman or superintendent, depending upon the particular job, size and weight of piles, and the plant used.

For hand driving with mauls or a light-weight (20 or 25 lb.) power hammer, a crew of about three or four men is usually satisfactory. For driving with a medium-weight power hammer,

a crew of four to six men may be satisfactory. A larger crew is usually required for long heavy piles and heavy equipment.

For pulling, a crew of three or four men may be used with hand equipment such as levers and simple block and tackle. A crew of four or five men or more may be needed with a power hoist and an inverted hammer, depending on size and weight of the piles.

For waling, a crew of two or more men should be used, depending on the amount of waling to be done and the size of the timbers used. The amount of waling cut, framed, and placed per labor-hour may vary from about 12 to 75 ft. b.m., or from 13 to 80 labor-hours may be required per 1,000 ft. b.m. About 150 to 400 ft. b.m. may be removed per labor-hour, or 2.5 to 7 labor-hours will be needed for removing 1,000 ft. b.m.

The amount of work done per man per hour will vary greatly depending on the various factors mentioned in Art. 5 on Factors Affecting Piling Costs. Perhaps the best way is to base the estimate on the number of square feet of wall surface per labor-hour with kind of soil, depth driven, and equipment used as variables. Note that the kind of soil does not affect labor for placing. For sheet piling, approximate labor outputs are as follows:

TABLE 4-1.—APPROXIMATE LABOR REQUIRED FOR SHEET PILING

Operation	Square feet of surface* per labor-hour	Labor-hours per 100 sq. ft. of surface
Placing or setting piles	15–30	3 – 7
Driving piles	10–40	2.5–10
Pulling piles	15–50	2 – 7

* This refers to the surface area of the wall or of one side of the pile.

Diagram 4-3 (page 562) may be used for estimating the labor costs for sheet piling.

9. Equipment or Plant for Sheet Piling.—The amount, kind, and size of equipment used (and the costs also) will vary with the kind of soil and the size, weight, and length of the piles.

For placing light (and comparatively short) wooden and steel sheet piling, no equipment is required as the placing may be readily done by hand. The placing of longer and heavier piles

may be done by the pile-driving equipment, or by separate equipment such as gin poles, derrick, or cranes. A crawler crane is very satisfactory.

The equipment used for driving may be hand mauls and sledges, light power hammers handled by one or two men, drop hammers with frames and hoisting equipment, medium power hammers suspended by a crane or derrick, or heavy power hammers with heavy frames and other equipment. When practical, the equipment should be mounted so that it may be readily moved as required.

The equipment used for pulling may be rope and hand lever of timber, block and tackle, jacks, hand hoists, power hoists, or inverted power hammers as the case may be, depending on the difficulties encountered in starting and pulling the piles, such as kind of soil, depth driven, and weight of pile.

The cost of the equipment used will vary from a few cents per hour for simple hand equipment up to several dollars per hour for the larger types of power equipment. Costs of transportation of equipment to and from the job and of erection and dismantling must be included. Operating costs may or may not include wages of operator and helpers. For example, the hourly operating cost of a small power hammer (25- to 100-lb. ram) with an air compressor (including fuel and compressor operation) will be about $2 to $5 per hour. A crawler crane and operator for handling and placing piles may cost $2 to $7 per hour. A medium-weight power hammer with a crane and power equipment with two men may cost about $7 to $15 per hour. Larger power hammers and equipment with two men may cost about $10 to $25 per hour. Drop hammers with frames and hoists and two men may cost about $10 to $25 per hour, depending on weight of hammer and size of frame.

Diagram 4-4 (page 563) may be used for estimating the plant or equipment costs for sheet piling.

10. Overhead and Profit.—Owing to the hazards accompanying sheet-piling work, the percentages assigned to overhead and profit are comparatively high. As stated in Art. 6 on Preparation of Estimates, percentages for overhead may range from 15 to 50 per cent when based on labor costs alone or from 10 to 30 per cent when based on labor and plant costs. Profit usually ranges from 10 to 35 per cent of all other costs.

11. Wooden Sheet Piling Estimates.—Planks 2 in. thick are commonly used for wooden sheet piling. However, when the depth is fairly great, the load restrained is fairly large, or when the wales are spaced some distance apart, thicker piles, say 3 or 4 in., should be used. In general, 2-in. plank is suitable for depths up to 10 or 12 ft., 3-in. plank for depths from 10 to 20 ft., and 4-in. plank for depths from 15 to 25 ft., depending on conditions. Wooden sheet piling is rarely used for depths exceeding 20 ft.

Rangers should be spaced apart horizontally from 3 to 6 ft. The spacing should be closer near the bottom of the excavation. For excavation up to 10 ft. deep, 4-by-4 or 4-by-6 rangers spaced not over 4 or 5 ft. apart with braces not over 6 or 8 ft. apart will usually be satisfactory. For excavations up to about 15 ft., 6-by-6 or 6-by-8 rangers may be needed. Excavation over 15 ft. in depth may require 8-by-8 or larger timbers. Sizes of cross braces in trenches will vary from 4 by 4 for a trench width of 3 or 4 ft. up to about 8 by 8 for a trench width of 12 ft. or so. Diagram 4-1 shows the cost per square foot of wooden sheet piling for varying thicknesses of piles and costs per 1,000 ft. b.m.

TABLE 4-2.—APPROXIMATE LABOR OUTPUT FOR INSTALLING WOODEN SHEET PILING

Depth driving, ft.	Method of driving	Sq. ft. of surface per hr. per man		Labor-hr. per 100 sq. ft. of surface	
		Place, drive, and brace	Place, and drive only	Place, drive, and brace	Place and drive only
5	By hand with maul	10–16	14–25	6.0–10.0	4.0– 7.0
10		9–14	12–20	7.0–11.0	5.0– 8.5
15		8–12	10–16	8.0–12.5	6.0–10.0
10	By light power hammer	12–20	16–30	5.0– 8.0	3.3– 6.5
15		10–18	14–27	5.5–10.0	3.7– 7.0
20		8–16	13–24	6.0–12.5	4.1– 7.5
25		7–15	12–22	6.5–14.0	4.5– 8.5

Two-inch plank may be driven by hand in fairly soft soil up to 6 or 8 ft. in depth. A light power hammer is usually required for greater depths and for harder soils. Wooden sheet piles

may be driven all the way by hand when it is possible to keep the excavation at or near the foot of the piles.

The approximate labor output for man per hour for placing, driving, and bracing wooden sheet piling is given in Table 4-2. One gang is supposed to consist of two to four men.

The approximate labor output for removing braces and pulling piling for a gang of two to four men is given in Table 4-3.

TABLE 4-3.—APPROXIMATE LABOR OUTPUT FOR REMOVING WOODEN SHEET PILES

Depth pulled, ft.	Method of pulling	Sq. ft. of surface per hr. per man		Labor-hr. per 100 sq. ft. of surface	
		Piling and bracing	Piling only	Piling and bracing	Piling only
5	By hand with timber lever or puller	20–40	25–50	2.5–5.0	2.0–4.0
10		18–35	23–45	3.0–5.5	2.2–4.5
15		15–30	20–40	3.5–6.5	2.5–5.0
10	By block and tackle and hand hoist on gin pole	18–35	23–45	2.8–5.5	2.2–4.4
15		16–30	20–40	3.3–6.2	2.5–5.0
20		14–26	18–35	3.8–7.1	2.8–5.6
25		12–23	16–30	4.3–8.3	3.3–6.2
10	Start with power hammer and pull by power hoist	23–50	28–60	2.0–4.3	1.7–3.6
15		21–46	25–55	2.2–4.8	1.8–4.0
20		19–42	23–50	2.4–5.3	2.0–4.4
25		17–38	21–45	2.6–5.9	2.2–4.8

Diagram 4-3 shows the relations among hourly labor wages, labor output per hour, and costs per square foot of surface. This diagram may be used either for placing and driving or for pulling the sheet piles when the hourly output per man per hour can be reasonably assumed.

Equipment costs will depend on equipment used. For hand driving by mauls and pulling by timber levers, an allowance of a cent or so per labor-hour will usually be satisfactory. A small power hammer (20- to 25-lb. ram) with an air compressor (and no special operator) may cost about \$1 an hour plus transportation to and from the job. Gin poles with block and tackle or other hand hoists may cost about \$0.25 to \$1 an hour plus

transportation. A heavier power hammer (say with a ram from 100 to 500 lb.) with a movable crane, compressor, fuel, and one operator may cost about \$3 to \$8 per hour plus transportation. When the equipment must be erected and later dismantled, these costs must be included. Overhead and profit percentages will vary about as stated in Art. 10 on Overhead and Profit.

12. Illustrative Estimate.—Prepare a complete estimate of the cost of installing and removing wooden sheet piling and bracing for an excavation 60 ft. wide, 100 ft. long, and 10 ft. deep in fairly soft soil. The sheet piles are 2 by 8 in. in size by 12 ft. in length (the piles must be 2 ft. longer than the excavation depth).

Wales are 2 lines of 6- by 6-in. timbers.

Braces are 3 by 8 in. in size, and there are required 34 each of lengths of 9 and 12 ft.

Stakes are 6 by 6 in. in size and 6 ft. long and 34 are needed.

Cost of lumber is \$100 per 1,000 ft. b.m. delivered at the job.

Salvage value is estimated at 60 per cent.

Cost of trucking lumber from job to contractor's yard and piling is \$2.10 per 1,000 ft. b.m.

Spikes (estimated at 20 lb. per 1,000 ft. b.m.) cost \$0.07 per pound.

Labor wage is \$1.00 an hour.

Piles are to be hand driven by mauls and hand pulled by a timber lever.

All overhead costs, including all insurance and supervision, is assumed as 30 per cent of the labor cost.

For profit, 10 per cent of the total costs is to be allowed.

Materials estimate:

Sheet piling	$= (100 + 100 + 60 + 60)12 \times 2$	= 7,680 ft. b.m.
Wales	$= (100 + 100 + 60 + 60)2 \times \frac{6 \times 6}{12}$	= 1,920 ft. b.m.
Braces	$= 34\left(\frac{3 \times 8}{12}\right)(9 + 12)$	= 1,428 ft. b.m.
Stakes	$= 34\left(\frac{6 \times 6}{12} \times 6\right)$	= 612 ft. b.m.
		11,640 ft. b.m.
Allow about 5 or 6 per cent for waste, say		= 660 ft. b.m.
Total		= 12,300 ft. b.m.

Say 12,300 ft. b.m. at \$100 per 1,000	= \$1,230
Deduct salvage value of 60 per cent	= 738
Net cost of lumber	= \$ 492
Spikes, 20 × 12 × \$0.07	= 17
Trucking costs for taking pulled piling and bracing to contractor's yard and piling = 12.3 × \$2.10	26
Total material costs	= \$ 535

Labor costs of placing and driving piles and installing bracing, assumed at 12 sq. ft. of wall surface per man

per hour, or 8.33 labor-hours per 100 sq. ft. of wall surface = (100 + 100 + 60 + 60)12 × $1 × 0.0833	= $320
Labor costs of removing wales and pulling piles, at 30 sq. ft. of surface per man per hour, or 3.33 labor-hours per 100 sq. ft. of wall surface = (100 + 100 + 60 + 60)12 × $1 × 0.0333 =	128
Total labor cost	= $ 448
Overhead at 30 per cent of labor cost	= 134
Total costs except profit	= $1,117
Profit at 10 per cent	= 112
Total estimate for job	= $1,229

Cost per square foot of wall surface = $1,229 ÷ 3,840 = $0.329

If desired, separate estimates could be prepared for the piling and for the bracing (see Art. 17 of this chapter on Timber Bracing for Cofferdams).

13. Steel Sheet Piling Estimates.—Steel sheet piling varies considerably in net width and in weight per square foot of pile. Extreme ranges in width are from about 7 to 20 in., with 15 of 16 in. being common. Ranges in weights are from about 15 to 40 lb. per square foot of wall, depending on the horizontal thrusts to be resisted by the piling and the bracing provided. Steel sheet piling should be used where watertightness of the wall is essential. As steel sheet piling may be pulled and used many times, from eight or ten to fifty, it is economical for use when compared with other materials. As steel piling may be readily spliced, it may be driven to a considerable depth. Lengths of piling (without splices) are available up to about 40 or 50 ft.

Bracing for steel sheet piling is often required, and should be provided about as for wooden sheet piling. Sometimes the heavier weights do not require bracing, and in some instances the bracing timbers may be larger and spaced farther apart.

As steel sheet piling is sold by the pound, it is necessary to know the length of pile, net width of pile, and weight per foot of length or per square foot of surface when preparing estimates. As previously stated, the price of steel sheet piling is about $2 to $3 per 100 lb. at the mill plus freight and other transportation charges to the job. The salvage value is very high, ranging from about 70 to 95 per cent. Steel sheet piling may be rented at a cost of $1 to $2 per 100 lb. plus transportation.

Diagram 4-2 shows the relation among the cost of steel sheet piling per 100 lb., the weight per square foot of wall surface, and the cost per square foot.

The approximate outputs per labor-hour for placing, driving, and bracing steel sheet piling and for removing the bracing and pulling the piling is about the same as that for wooden sheet piling for like depths. Tables 4-4 and 4-5 give approximate values.

TABLE 4-4.—APPROXIMATE LABOR OUTPUT FOR INSTALLING STEEL SHEET PILING

Depth driven, ft.	Method of driving	Sq. ft. of surface per hr. per man		Labor-hr. per 100 sq. ft. of surface	
		Place, drive, and brace	Place and drive	Place, drive, and brace	Place and drive
5	By hand with maul	10–16	14–25	6.0–10.0	4.0– 7.0
10		9–14	12–20	7.0–11.0	5.0– 8.5
15		8–12	10–16	8.0–12.5	6.0–10.0
10	By light power hammer	12–20	16–30	5.0– 8.0	3.3– 6.5
15		10–18	14–27	5.5–10.0	3.7– 7.0
20		8–16	13–24	6.0–12.5	4.1– 7.5
25		7–15	12–22	6.5–14.0	4.5– 8.5
10	By medium power hammer with crane or derrick	14–25	20–35	4.0– 7.0	2.8– 5.0
20		12–22	17–31	4.5– 8.5	3.2– 6.0
30		10–20	14–28	5.0–10.0	3.6– 7.0
40		8–18	12–25	5.5–12.0	4.0– 8.5
50		7–16	10–23	6.0–14.0	4.3–10.0

Diagram 4-3 may be used for estimating labor cost per square foot for either placing, driving, and bracing, or removing bracing and pulling steel sheet piling.

Equipment costs will vary greatly depending upon equipment used. These will be about the same as those stated in the preceding article. For power hammers with heavier rams than those mentioned, the hourly costs will be greater. Transportation costs to and from the job and erection and takedown costs should not be omitted.

Overhead and profit percentages will be about as stated in Art. 10 on Overhead and Profit.

Contract figures on steel sheet piling work in 1945 gave prices ranging from $0.75 to $2.30 per square foot of wall surface,

Piles will be pulled by a gang of 3 men with a timber lever.
Wages of men are $1 per hour.
Overhead costs are 30 per cent of labor costs.
Profit is 10 per cent of total costs.

Materials estimate.

Sheet piling = (100 + 100 + 60 + 60)12 × 23 = 88,320 lb.

$$\text{Cost of piling less salvage} = \frac{88{,}320}{100} \times \$3.70(1.00 - 0.95) = \$163$$

$$\text{Trucking to and from the job} = \frac{88{,}320}{2{,}000} \times \$0.85 \times 2 \quad = \quad 75$$

$$\text{Cost of steel piling} \quad = \overline{\$238}$$

$$\text{Wales} = (100 + 100 + 60 + 60)2 \times \frac{6 \times 6}{12} = 1{,}920 \text{ ft. b.m.}$$

$$\text{Braces} = 34\left(\frac{3 \times 8}{12}\right)(9 + 12) = 1{,}428 \text{ ft. b.m.}$$

$$\text{Stakes} = 34\left(\frac{8 \times 8}{12}\right)6 = 612 \text{ ft. b.m.}$$

Total lumber	=	3,960 ft. b.m.
Allow 6 per cent for waste	=	240 ft. b.m.
Total	=	4,200 ft. b.m.

$$\text{Lumber cost } \left(\frac{4{,}200}{1{,}000}\right)\$100(1.00 - 0.60) = \$168$$

Trucking to yard 4.2 × $2.10	=	9		
Spikes and bolts	=	15		
Cost of waling and bracing	=	$192		
Cost of materials			= $	430

Cost of labor for placing and driving piles and placing bracing at an average hourly wage of $\left(\frac{\$1.40 + 3 \times \$1}{4}\right)$, or $1.10 per hour, and an assumed output of 18 sq. ft. of wall surface per hour, or 5.5 labor-hours per 100 sq. ft. of wall surface, will be

$$(100 + 100 + 60 + 60)12 \times \$1.10 \times 0.055 = \$232$$

Cost of removing and pulling with 3 men at $1 per hour and 3.33 labor-hours per 100 sq. ft. of wall surface (30 sq. ft. per hour)

$$= (100 + 100 + 60 + 60)12 \times \$1 \times 0.0333 = \underline{128}$$

Total labor cost = $ 360

Hours for driving and bracing (4 men)

$$\frac{(100 + 100 + 60 + 60)12}{18 \times 4} = 53.33$$

Cost of equipment = 53.33 × $1.20 + $7	=	71
Overhead at 30 per cent of labor cost	=	108
Total costs except profit	=	$ 969
Profit at 10 per cent	=	97
Total estimate for job	=	$1,066

Cost per square foot of wall surfaces = $1,066 ÷ 3,840 = $0.278

If desired, separate estimates could be prepared for the piling and bracing (see Art. 17 of this chapter on Timber Bracing for Bulkheads).

NOTE: By comparing this cost with that found for wooden sheet piling in the illustrative estimate of the preceding article, it is seen that the steel piling is cheaper according to the data given. If cheaper wooden sheet piling were available, the material costs would be reduced. In general, wooden sheet piling is often cheaper than steel sheet piling for depths of 15 or 20 ft. or less and in soils in which wood plank of 2 to 3 in. in thickness may be used. Steel sheet piling is often cheaper than wooden sheet piling for depths in excess of 20 ft. and also when a thickness of 4 in. or more is required for the wooden piling.

15. Concrete Sheet Piling Estimates.—Concrete sheet piling is often used when the piles are to remain in place. These piles are, in general, larger and heavier than most sheet piles of wood or steel. Consequently, power equipment is used for placing and driving. This piling is usually sold at so much per pile, with length, dimensions, and other details being specified. Approximate estimates of the cost per square foot of wall surface for reinforced concrete sheet piles will vary largely with the thickness of the pile, other factors being constant. This cost may range from about $0.35 to $0.85 per square foot of wall surface for piling 6 in. thick to $0.55 to $1.30 per square foot for piling 12 in. thick. Concrete sheet piling may be designed to resist horizontal thrusts either with or without waling and bracing.

Labor and equipment costs of placing and driving a reinforced concrete sheet pile may be comparatively high because of the larger size and heavier weight when compared with wooden and steel sheet piles. Heavier and sturdier equipment must be provided. However, when the sheet piling is to be left in place, reinforced concrete sheet piling is sometimes economical when compared with the wood and steel sheet piling of equal strength.

The same methods may be used for estimating the cost of concrete sheet piling as were used in the two preceding articles, due allowance being given to the heavier weight of the pile and the stronger equipment needed for handling and driving. The output per labor-hour will usually be a little less than the values given in Table 4-4.

When preparing the estimates, allowances must be made for grouting, if this is required for making the joints watertight, and for cutting the tops of the piles to grade.

16. Trench-piling and Bracing Estimates.—The bracing required in trenches will vary from none when the walls are firm and the trench is not deep to skeleton bracing when only a few braces are needed, to light sheet piling in soft soil, to fairly heavy sheet piling and bracing in very soft and loose soil.

Skeleton piling and bracing consist of placing planks (usually 2 by 4, 2 by 6, or 2 by 8), either vertically or horizontally, every few feet on the opposite sides of the trench and using braces (2 by 4 or 4 by 4) between the planks to keep them in position. The planks may be placed closer together or farther apart as conditions require. The cost of materials for skeleton bracing is not great, as comparatively little material is required and this can be almost all salvaged. The labor cost is also small as the planks and braces can be put in place by the diggers as needed without taking but a few minutes of their time out of each hour. The cost of skeleton piling and bracing is sometimes included in the estimates of cost of digging and of tools, no separate estimate being made.

Light piling and bracing is usually composed of wood and may be put in place as the trench is dug. The planks used for sheet piling are placed vertically and close together. Wales and cross braces are used to keep the piling in place. The costs of such piling and bracing may be estimated according to the method given in Art. 11 on Wooden Sheet Piling Estimates and using comparatively high labor outputs per hour both for placing and removing piling and bracing. The planks used for piling are usually 2 by 6 or 2 by 8 in size, the wales may be 2 by 6 or 4 by 4 in size, and the cross braces about 4 by 4.

Medium and heavy sheet piling and bracing for trenches may consist of either wood or steel sheet piling with wooden wales and wooden or steel cross braces. This sheet piling is usually placed and driven as the trench is dug. In very soft or loose soils, the bottoms of the piles should be kept a few inches or more below the bottom of the trench. With soils not quite so loose, the trench may be first dug a little below the bottoms of the piles and then the piles may be driven as far as the trench bottom. In this method, the driving is much easier than driving the piles into the soil in advance of the digging. The method given in Art. 11 on Wooden Sheet Piling Estimates may be used for estimating the costs of placing, driving, bracing, and removing

the sheet piling and braces, due consideration being given the kind of work. The sheet piling may be a light steel piling if water is to be kept out, or 2-by-6 or 2-by-8 planks if the trench is not too deep (say 8 or 10 ft. or less) or the horizontal thrust of the soil too great, or 3 by 6 or 3 by 8 for deeper trenches and greater soil pressure. Timber 4 in. thick or Wakefield piling may be used if needed. Wales are 4 by 4 or 4 by 6 in. in size and spaced from about 5 to 3 ft. apart as the depth of the trench increases. Cross braces 4 by 4 or 4 by 6 in. in size should be placed in contact with the wales and about 8 to 5 ft. apart; the deeper the trench, the closer the spacing.

17. Timber Bracing for Cofferdams.—Timber is usually used for the bracing in cofferdams. This bracing usually consists of horizontal rangers braced by horizontal struts extending across the cofferdam in one or both directions. In some instances, diagonal braces are used at the corners and at ends where the cofferdam is rectangular in shape, with horizontal braces in one direction. Vertical wales, struts, or posts may be required to keep the horizontal members in place.

The timbers used for cofferdam bracing will be comparatively large so as to carry the load, prevent buckling, and provide free spaces in which the men and machines may work without too much interference. The timbers used may vary from about 4 by 4 to 12 by 12 in. in size.

The amount of material required is usually expressed in feet board measure, with size and length given. To determine the correct amount, a complete take-off should be made showing all sizes and lengths. Some allowance must be made for cutting and waste. This allowance may range from about 5 to 15 per cent.

The cost of the material will be the first cost less salvage value plus transportation to and from the job, as the case may be.

The labor required will vary with the skill of the crew, the size of the timbers to be handled, and the working conditions. Carpenters and handy men are usually satisfactory. Labor costs will depend upon the items mentioned and the labor wage. Timbers from 4 by 4 to 8 by 8 in. in size may be placed and removed by hand. For larger timbers, a derrick or crane will usually be needed. The labor required is given in Table 4-6. Installing includes cutting, framing, and erecting.

The equipment used will vary with the tools available, size of timbers and number of them. The usual hand tools such as saws, hammers, axes, and bits and braces will always be needed. Power tools, such as portable power drills and power saws, should be provided when practicable as they will save much hand labor. A stationary power saw is sometimes used to saw the timbers to exact lengths. A hand hoist, derrick, or crane is helpful in handling (placing and removing) medium- and large-sized timbers. For the larger jobs and larger sizes of timbers, a power hoist of some kind (derrick or crane) is desirable.

TABLE 4-6.—LABOR REQUIRED FOR INSTALLING AND REMOVING TIMBER BRACING IN COFFERDAMS

Size of timber	Crane or derrick	Installing		Removing	
		Ft. b.m. per hr.	Hr. per 1,000 ft. b.m.	Ft. b.m. per hr.	Hr. per 1,000 ft. b.m.
4 by 4	None	20–50	20–50	250–400	2.5–4.0
6 by 6	None	16–40	25–65	200–350	3.0–5.0
8 by 8	None	12–30	35–85	150–300	3.5–6.5
8 by 8	Yes	20–40	25–50	200–350	3.0–5.0
10 by 10	Yes	18–35	30–55	175–300	3.5–6.0
12 by 12	Yes	15–30	35–70	150–250	4.0–7.0

The cost of equipment will vary with the kind and size of tools and machines used. The cost of small hand tools may be a few cents per day per laborer. A hand hoist may cost up to \$0.05 or \$0.10 per hour. Small power tools such as drills and saws may each cost \$0.05 to \$0.20 per hour. A hand derrick or crane may cost \$0.20 to \$0.50 per hour, and a small power derrick or crane may cost \$0.25 up to \$1.50 per hour with operator extra (or \$1.50 to \$4 per hour with one operator). These costs are approximate.

As this type of work is hazardous and often difficult to estimate accurately, the labor estimate should be liberal, the overhead fairly high (say 15 to 50 per cent when based on labor costs), and the profit reasonably high (say 10 to 35 per cent).

The items entering into a complete estimate will be materials, labor, plant or equipment, overhead, and profit.

C. BEARING PILES

18. Materials for Bearing Piles.—The materials commonly used for bearing piles are wood, steel, reinforced concrete, and combinations of steel and concrete such as a steel shell filled with concrete.

Wooden bearing piles are usually round and tapered in shape, about 6 in. in diameter at the small end and 12 to 20 in. in diameter near the butt, and vary in length from a few feet up to a maximum of about 90 ft. Wooden bearing piles are usually priced at so much per lineal foot, this unit price varying with the size and length of the pile, the nearness to the source of supply, and the transportation to the job site. For example, in December, 1945, the price of shortleaf pine piles f.o.b. cars New York were approximately as follows:

Dimension		Length, feet	Price per lineal foot
Points, inches	2 ft. from butt, inches		
6	12	30–50	$0.34
6	12	50–59	0.35
6	12	60–69	0.36
6	14	50–69	0.41
6	14	70–79	0.43
5	14	80–85	0.54
5	14	85–89	0.57

Steel bearing piles, usually of I or H structural sections, have been used satisfactorily in many places, the H sections (sometimes called CB or WF sections) being preferred. According to the steel companies, load tests and life tests were very satisfactory. Steel piles are adaptable when they can be driven through loose, unstable soil or fill to a relatively hard strata, when considerable penetration in hard driving material is required, when extremely great penetration is necessary to secure adequate bearing capacity, and where piling may be susceptible to attack by borers or other insects. The size of the H sections may vary from about 8 by 5½ in., net area of 5.00 sq. in., and a weight of 17 lb. per lineal foot up to about 36 by 16½ in., net area of 88

sq. in., and a weight of 300 lb. per lineal foot. The sections are readily obtainable in lengths up to about 40 ft., and may be spliced. Prices are the same as those for structural shapes, and are equal to mill base prices, plus extras, plus freight and other transportation. Mill prices usually range from \$2 to \$3 per 100 lb. Dealer prices in large cities may range from \$2 to \$5 per 100 lb. Transportation from dealer, railroad yard, or contractor's yard to the job will vary with the length of haul and other conditions. The resulting price of steel bearing piles at the job may vary from about \$3 and up per 100 lb.

Reinforced concrete and combination steel and concrete bearing piles of various types have been designed, made, and used. Concrete bearing piles of the larger sizes and lengths (up to 100 ft. long) are economical. Prices are usually quoted at so much per pile f.o.b. at the casting yard, with dimensions, mix, reinforcement, and other details as specified. Transportation charges to the job must be added. Prices per cubic yard of reinforced concrete may range from \$20 to \$50 per cubic yard (say from \$5 to \$13 per 1,000 lb.), depending on cost of concrete materials, reinforcement, forms, labor, etc.

19. Labor for Bearing Piles.—The labor required for placing, driving, and other operations connected with bearing piles will depend upon the kind of soil, size of pile, depth driven, and equipment used. These conditions vary so greatly on different jobs that it is practically impossible to give any general rules by which the labor may be estimated. Some authorities have tried to estimate the labor required per lineal foot of driven pile with allowances for soil conditions and size of pile. Other estimators have tried to estimate the labor required per pile, with allowances for soil conditions and size and length of pile. When there are a large number of piles of about the same size to be driven to about equal depths, either method is satisfactory. The second method (labor per pile) is more satisfactory when there are several sizes of piles to be driven to unequal depths.

The crew required will vary greatly, depending on the particular job. For example, on a job using small piles, the crew may consist of an operator, a foreman (working with men), and one to three helpers. The operator may act as foreman in some cases. For medium-sized piles, there may be a foreman, one or two operators, depending on equipment used, and two to six

helpers. With large heavy piles, there may be a foreman, an operator or two for the pile driver, an operator for the crawler crane for handling and placing piles, and four to ten helpers.

Diagrams 4-5 and 4-6 (pages 564 and 565) may be used for estimating labor costs for bearing piles.

20. Equipment or Plant for Bearing Piles.—The equipment or plant required for bearing piles will be about the same as that required for sheet piling except that heavier and larger equipment may be needed for the heavier and larger piles.

The time required to drive a bearing pile is usually greater than that required for a sheet pile, because whereas a sheet pile is driven to a certain depth, the bearing pile is driven until a hard stratum is reached or until the pile is judged capable of bearing the desired load. The time required to drive a bearing pile the last few feet is much greater in proportion. Note formulas given for bearing piles in Art. 2 on Placing and Driving.

The equipment used may be a derrick and drop hammer, a crane and power hammer, or a jet with a crane and light hammer. The pile-driving equipment may be used for picking up and placing the piles, or separate equipment (such as a crawler crane) may be used. Cushions or caps are required to protect the pile tops in driving. Followers may be needed when the piles are to be driven below the surface of the water or of the ground. Leads and guides are usually required unless a suitable templet (say of timber) is provided for aligning and guiding the piles. Sometimes other equipment is required to straighten the piles as they are driven. The equipment selected should be suitable for the kind of soil, and the size, weight, and length of the piles. Some equipment may be needed for cutting the tops of piles and capping them.

The cost of pile-driving equipment will vary greatly with the size and kind used. The cost is usually given as so much per hour, including fuel, power, operator, and minor repairs. Transportation to and from the job, erection and dismantling, general repairs, and the general overhead are usually added as separate items. Approximate hourly operating costs for pile-driving equipment may vary from about \$2 to \$4 per hour with one operator to \$10, \$15, \$20, or more per hour with one or more operators. The cost of a crawler crane with one operator may vary from about \$2 to \$7 per hour. Jetting equipment with

pumps and an operator may cost about $3 and up per hour. The costs of templets, guides, blocking, timbering, etc., must not be omitted.

Diagrams 4-7 and 4-8 (pages 566 and 567) may be used for estimating plant or equipment costs for bearing piles.

For jetting operations, pumps of adequate capacity are needed because volume of water is more important than pressure. The size of pipe usually varies from 1.5 to 2.5 in., and the size of the nozzle from 0.5 in. up to the size of the pipe (*i.e.*, no contraction). Two pipes and nozzles with hose and other connections should be provided. The maximum water pressure at the pump may vary from 100 to 225 lb. per square inch, and the volume of water discharged from 50 to 200 gal. per minute (say 50 to 150 gal. per minute per pipe). A suitable water pump and equipment with power and one operator may cost $2 to $5 per hour (depending on capacity of pump (and number of jet pipes), plus transportation to and from the job.

The rate of driving piles may vary from 50 lin. ft. or more per hour for small piles in soft soil up to only a few feet per hour for the larger, heavier, and longer piles in hard ground. In preparing estimates, the time required to drive one pile, the number of piles driven per hour, or the average number of lineal feet driven per hour may be chosen. The accuracy of the estimate will depend upon the estimator's judgment and his experience on somewhat similar jobs.

Some outputs are as follows:

220 wooden piles, 65 ft. long, in 9 hr. in *very soft* ground.

100 to 200 piles, about 40 ft. long, in 8 hr., in soft ground.

20 to 60 piles (average 35), 35 to 40 ft. long, in 8 hr., in medium soil.

10 to 35 piles, about 50 ft. long, in 9 hr., in fairly hard soil.

21. Overhead and Profit.—As pile-driving operations are hazardous and difficult to estimate as to time and cost, the percentages allowed for overhead and profit should be comparatively large. For overhead, the percentage may range from 15 to 50 when based on labor costs alone, or from 10 to 35 when based on cost of labor and equipment. The percentage charged for profit may range from 10 to 25 of the sum of all other costs.

22. Bearing Pile Estimates.—The different items affecting the costs of piling were discussed in Art. 5 on Factors Affecting

Piling Costs. As stated in Art. 6 on Preparation of Estimates, the main items are, materials, labor, equipment or plant, overhead, and profit. The way of estimating piling costs given in that article may be followed, using hours required per pile (or piles per hour), or hours per 100 lin. ft. (or lineal feet per hour) in step 4. Some estimators prefer to compute the hourly costs of crew (labor) and plant considered together, and to estimate the output of this crew and plant in hours per pile, piles per hour, or lineal feet per hour.

Some prices (1945) gleaned from various sources follow:

Piles Driven in Place	Per Lineal Foot
Untreated timber piles, small	$0.51–$1.05
Untreated timber piles, small	0.63– 1.20
Treated timber piles, small	0.85– 1.55
Untreated timber piles, medium	1.50– 1.85
Treated timber piles, 32 ft	1.50– 1.80
Treated timber piles, medium	1.54– 2.75
Treated timber piles, 60 ft	1.80– 2.00
Treated timber piles, large	1.85– 2.20
Douglas fir piles, 80 ft	2.15– 2.75
Treated timber piles, very large	3.00– 5.20
Steel bearing piles, 40–50 ft	2.80– 4.40
Reinforced concrete piles, 30–45 ft	3.50– 6.00
Reinforced concrete piles, large	5.00– 8.00

The prices vary greatly, ranging from about $0.50 per lineal foot for small wooden piles up to about $5 per lineal foot for fairly large piles. Very large and heavy concrete and steel piles will be more expensive.

Diagrams 4-5 to 4-10, inclusive, (pages 564–569) show relations among hourly costs of crew, hourly costs of plant, hourly costs of crew and plant, hours per pile (piles per hour), hours per 100 lin. ft. (lineal feet per hour), costs per pile, and costs per lineal foot.

The following three bearing-pile estimates were based on 1939 costs. To bring the estimates up to 1946 cost levels (approximately), the main items should be increased by about the following percentages:

Materials delivered at the job site: timber, 45 per cent; steel, 25 per cent; concrete, 35 per cent.

Labor: all labor costs should be increased by about 50 per cent.

Equipment: all equipment costs should be increased by about 30 per cent.

Overhead: all overhead costs should be increased by about 50 per cent.

Profit: no change in this percentage.

In these three estimates no allowance is made for job hazards, unavoidable delays, labor troubles, and other unforeseen difficulties.

23. Illustrative Estimate on Wooden Bearing Piles.—Estimate the cost in place of 288 wooden bearing piles each 40 ft. long and costing $0.38 per lineal foot f.o.b. siding. Cost of transporting to job is $0.92 per pile. Cost of suitable pile driver (crawler crane and power hammer) and operator is $5 per hour. Cost of transportation to and from the job is $34. Cost of templet, etc., is estimated at $42 for the job. Crew is composed of 1 foreman at $1.50 per hour and 4 helpers at $0.80 per hour in addition to operator of pile driver. Overhead is 28 per cent of all labor costs, and profit is to be computed at 12 per cent of all other costs. Soil is medium with rock at 40 ft., requiring the ends of the wooden piles to be provided with metal caps at a cost of $0.28 per pile.

Material Costs:
- Cost per pile = ($0.38 × 40) + $0.92 + $0.28 = $16.40
- Cost per lineal foot = $16.40 ÷ 40 = $0.41
- Cost of 288 piles = $16.40 × 288 = $4,723.20

Labor costs (operator included with equipment):
- Hourly cost of crew = $1.50 + ($0.80 × 4) = $4.70
- Assuming this crew and equipment to place and drive 3 piles per hour in this soil (0.333 hr. per pile), hours required = 288 × 0.333 = 96
- Labor cost = $4.70 × 96 = $451.20
- Cost per pile = $451.20 ÷ 288 = 1.567
- Cost per lineal foot = $1.567 ÷ 40 = 0.0392

Equipment costs:
- Crane and hammer = $5 × 96 = $480.00
- Templets = 42.00
- Transportation = 34.00
- Total = $556.00
- Cost per pile = $556 ÷ 288 = 1.931
- Cost per lineal foot = 0.0483

Overhead costs = $451.20 × 28 per cent = $126.34
- Cost per pile = $126.34 ÷ 288 = 0.439
- Cost per lineal foot = 0.0110

Profit = ($4,723.20 + 451.20 + 556.00 + 126.34) × 12 per cent = $702.81
- Cost per pile = 2.440
- Cost per lineal foot = 0.0610

Summary:

Item	Cost per Lineal Foot	Cost per Pile	Total Costs
Materials	$0.4110	$16.400	$4,723.20
Labor	0.0392	1.567	451.20
Equipment	0.0483	1.931	556.00
Overhead	0.0110	0.439	126.34
Profit	0.0610	2.440	702.81
Total	$0.5695	$22.777	$6,559.55

long and costing \$37 each at casting yard plus \$1.40 each for transportation to job. Cost of suitable pile driver (crawler crane and power hammer) and operator is \$7.25 per hour. A small crawler crane and operator at \$3.25 per hour will be used for handling piles at job. Cost of transportation of equipment to and from job is \$62. Cost of templets is estimated at \$42 for the job. Crew is composed of 1 foreman at \$1.50 per hour and 6 helpers at \$0.80 per hour in addition to operators for pile driver and crane. Soil is medium with rock at 40 ft. depth.

Material costs:		
Cost per pile = \$37.00 + \$1.40	=	\$38.40
Cost per lineal foot	=	0.96
Cost of 128 piles = \$38.40 × 128	=	4,915.20
Labor costs (operators included with equipment):		
Hourly cost of other labor = \$1.50 + (\$0.80 × 6)	=	\$6.30
Assume this crew and equipment to place and drive 1.6 piles per hour (0.625 hr. per pile).		
Hours required = 128 × 0.625	=	80
Cost of labor = \$6.30 × 80	=	\$504.00
Cost per pile = \$504 ÷ 128	=	3.9375
Cost per lineal foot	=	0.0984
Equipment costs (7.25 + 3.25)80 + 42 + 62	=	\$944.00
Cost per pile = \$944 ÷ 128	=	7.375
Cost per lineal foot	=	0.1844
Overhead costs. \$504.00 × 28 per cent	=	\$141.12
Cost per pile	=	1.103
Cost per lineal foot	=	0.0276
Profit (\$4,915.20 + 504.00 + \$944.00 + \$141.12) × 12 per cent	=	\$780.52
Cost per pile	=	6.098
Cost per lineal foot	=	0.1525

Summary:

Item	Cost per Lineal Foot	Cost per Pile	Total Cost
Materials	\$0.9600	\$38.400	\$4,915.20
Labor	0.0984	3.938	504.00
Equipment	0.1844	7.375	944.00
Overhead	0.0276	1.103	141.12
Profit	0.1525	6.098	780.52
Total	\$1.4229	\$56.914	\$7,284.84

Note that the labor costs of the two operators are included in the equipment costs and not in the labor costs.

The material costs of the piles, wages of men, and equipment costs selected in these three illustrative estimates were not based on actual jobs. The data assumed were chosen, not for the purpose of comparing the costs of these three types of bearing piles, but for the purpose of illustrating the preparation of cost estimates for bearing piles.

CHAPTER V

CONCRETE

1. Estimating Concrete Work in General.—A concrete construction job may be divided into the following divisions or parts in regard to quantities and units:

1. Excavation in cubic yards (see Chap. III for excavation estimates).
2. Forms in square feet of form surface.
3. Concrete in cubic yards or cubic feet.
4. Reinforcing steel in pounds or tons.
5. Finishing in square feet or square yards.
6. Curing in cubic yards or cubic feet, or in square yards or square feet.

The plant, overhead, and profit items may be readily apportioned among these six divisions, though some estimators prefer separate divisions for overhead and profit. The cost of cleaning up should not be omitted but should be preferably included in the overhead costs.

Each of these six divisions may be subdivided as follows:

a. Materials in units suitable for each kind of material.
b. Labor.
c. Plant.
d. Overhead.
e. Profit.

Most concrete work is estimated by the *unit-quantity* method instead of by the *total-quantity* method. Most form work is estimated in square feet of form surface, reinforcing steel in pounds, concrete in cubic yards, and finishing in square feet. Unit costs are first found, and then total costs are found for each item by multiplying unit costs by the number of units.

When it is desired to prepare estimates using the unit-quantity method and for different classes or kinds of concrete, the cost per cubic yard (or other suitable unit) of each class of concrete is computed. For example, in a reinforced concrete building the

classes of concrete would be foundations and footings, columns, beams and girders, floor slabs, etc. Then when preparing an estimate for one class, such as the columns, the estimator would compute costs per cubic yard and total costs, including such items as forms, reinforcement, concrete, finishing (if any), and curing. This method is used when it is necessary to submit bids or estimates of different kinds of concrete in place.

A complete list of materials, known as the take-off, is first prepared. The estimator tabulates all the different materials as to kind, number, size, weight, volume, or other units used. The selection of units for different materials will be explained in more detail in later paragraphs.

When estimating material costs, the costs of the materials at the job are usually computed. This cost includes first cost, freight, unloading, cartage, storage, inspection, testing, and insurance.

In estimating the quantity of labor required for any unit of work, the total number of labor-hours for each class of labor and each kind of work is listed. Total labor costs for any unit of work are found by multiplying the hours estimated for each class of labor by the corresponding wage rate per hour, and then adding results.

The selection of the plant to be used on any particular concrete job often depends upon the machinery and tools that the contractor has available for that job. Sometimes new equipment must be purchased, and this should be considered when estimating costs.

Plant costs usually include costs of transportation, installation, maintenance and repairs, operation, removal, interest on investment, and depreciation (proportionate part of the first cost of the plant). The labor costs of machine operators, such as hoisting engineers or firemen, are often included in the plant costs. For concrete work, plant costs are usually computed for each unit quantity or work, say per square foot or per 100 sq. ft. of form surface for forms, or per cubic yard of concrete, for example. Some estimators prefer hourly rates for the plant, based on the total time the plant is held available for the job, on the actual operating time, or on a combination of both.

Overhead costs include such general office and other labor costs that are not considered as direct productive labor on the

job. Other costs included are insurance, rents, office stationery, expense of plans and specifications, interest, legal expenses, traveling expenses, sundries, etc. These overhead expenses are often apportioned to the several parts of the job according to the sum of the materials, labor, and plant costs, or according to the labor costs of these parts. Overhead costs on concrete work may range from 10 to 35 per cent of the sum of the materials, labor, and plant costs or from 20 to 50 per cent of the labor costs alone.

Estimates for profit usually vary from 8 to 15 per cent of the total costs.

The estimating of excavation was covered in detail in Chap. III, and will not be considered in this chapter.

A. ESTIMATING FORMS

2. Units of Measurement.—The unit of measurement for forms should be the actual area in square feet of the surface of the concrete in contact with the forms. The estimated materials

TABLE 5-1.—UNITS OF MEASUREMENTS FOR FORMS

Forms For	How Measured
Floors	Total area in square feet
Walls	Total area in square feet. Forms may be placed on one or both sides
Columns	Circumference of the column in feet times the net height in feet from floor to floor
Column caps, drops, bands, etc	Total area in square feet
Roofs	Total area in square feet. When the slope of the roof with the horizontal exceeds 25 deg., the upper side of the roof requires forms
Footings	Total area in square feet of concrete surface next to forms
Beams and girders	Total area in square feet. For a beam, this is equal to the net length between columns or supports times the sum of the breadth and twice the depth
Staging and bridging	No definite rules. Total number of thousand board feet required should be computed
Moldings and cornices	Total number of lineal feet. Other dimensions should be noted
Window sills and copings	Total number of lineal feet. Other dimensions should be noted
Stairs	Total area in square feet, composed of area of the underside, areas of ends, and areas of risers

for forms should include materials for struts, posts, bracing, bolts, wire, ties, oiling, cleaning, and repairing, but should not include materials for staging and bridging. Forms for each different part of the structure should be listed and described separately. Forms for moldings, window sills, and copings are measured by the lineal foot. No deductions in form measurement are made for openings having an area of less than 25 sq. ft., because the extra labor in forming around the openings will often cost more than the value of the lumber saved. No allowance is made for construction joints except in very large structures such as dams.

3. Materials for Wooden Forms. *Quantities.*—The approximate quantities of materials required for wooden forms of different types are given in Table 5-2.

TABLE 5-2.—APPROXIMATE QUANTITIES OF MATERIALS REQUIRED FOR 100 SQ. FT. OF FORM SURFACE OF NEW WOODEN FORMS

Kind of forms	Lumber, board feet	Nails, bolts, and wire, pounds
Footings and piers	200–350	6–11
Walls and partitions	200–270	6– 9
Floors	180–280	6– 9
Roofs	200–300	6–10
Columns	190–320	6–11
Column caps	200–400	6–12
Beams and girders	300–700	8–16
Stairs	300–600	8–14
Molding and cornice*	200–800	6–15
Sills and lintels*	250–800	7–14

* Per 100 lin. ft.

When the work permits the re-use of certain types of forms, perhaps 50 to 80 per cent of these forms may be used again after repairs have been made. The extra lumber required for form repairs may vary from about 40 to 200 ft. b.m. per 100 sq. ft. of form surface.

On some jobs, the form lumber may be salvaged and used for other purposes. From 20 to 80 per cent may be so used, depending upon the job and the damage done in stripping and cleaning.

If the form surfaces are to be oiled, the amount of oil required may be estimated at ½ to 1 gal. per 100 sq. ft. of form surface.

Staging and bridging should be estimated separately for each job. No general values can be given for this work.

Costs.—The cost of form lumber delivered at the job may vary from about $45 to $130 per 1,000 ft. b.m. The cost of ordinary plywood, ⅝ or ¾ in. thick, may range from about $70 to $120 per 1,000 sq. ft. Special concrete-form grade fir plywood, 4- by 8-ft. panels, five-ply, sanded two sides, water-resistant glue, carload lots, per 1,000 sq. ft. of surface may cost from about $90 to $140. Many contractors prefer this special form plywood because of its higher salvage value, lower labor costs, and better surface when compared with ordinary lumber sheathing.

There is usually some salvage value of the old form lumber. When there is no salvage value, the costs will be comparatively high. The salvage value of the old form lumber may be 20 to 80 per cent of its original cost, depending upon care exercised by the workmen, and the possible uses to which the old lumber may be put. The salvage value of special concrete form plywood may range from 50 to 90 per cent.

Nails, bolts, and wire will cost about $0.05 to $0.07 per pound on the average, when purchased in quantity. The cost of nails, bolts, and wire will vary from about $0.35 to $0.90 per 100 sq. ft. of form surface.

Oil for oiling forms will cost a few cents per 100 sq. ft. of surface, say $0.03 to $0.07, depending on kind and price of oil.

Material Diagram.—Diagram 5-1 (page 570) may be used for estimating the materials cost of wooden forms when the cost per 1,000 ft. b.m. is known and the number of board feet required for 1 sq. ft. of form surface may be reasonably assumed.

4. Labor for Wooden Forms. *Quantities.*—The approximate amounts of labor required for various types of wooden forms are given in Table 5-3.

In general, the labor-hours per 100 sq. ft. of form surface will be less when special concrete fir plywood is used than when plain boards or shiplap are used.

Oiling or wetting the form surface will require a few minutes to about an hour for each 100 sq. ft. of form surface.

Staging and bridging should be estimated separately for each job, and no general values for this work can be given.

TABLE 5-3.—APPROXIMATE LABOR-HOURS REQUIRED FOR 100 SQ. FT. OF FORM SURFACE FOR WOODEN FORMS

Kinds of forms	Labor-hours per 100 sq. ft. of form surface			
	Assemble	Erect	Strip and clean	Repair
Footings and piers	3– 7	2–4	2–4	2–5 hr. for all types
Walls and partitions	5– 9	3–5	2–5	
Floors	3– 8	2–4	2–4	
Roofs	3– 9	2–5	2–4	
Columns	4– 8	2–4	2–4	
Column caps	5–11	3–7	2–5	
Beams and girders	6–10	3–4	2–5	
Stairs	6–12	4–8	3–5	
Molding and cornice*	5–11	3–9	3–5	
Sills and lintels*	4–10	3–6	3–5	

* Per 100 lin. ft.

Costs.—Form work is often all done by carpenters, but when possible, a combination gang of carpenters, handy men, and ordinary laborers should be used to save expense. The proportion of the different classes of laboring men will vary in any gang, but one-third carpenters, one-third handy men or rough carpenters, and one-third laborers will not be far from the average.

The average cost of laborers will be about as follows: carpenters $1 to $2 per hour, handy men or rough carpenters $0.80 to $1.60 per hour, and laborers $0.65 to $1.25 per hour. Wages will vary at different times and in different localities. Labor costs per man-hour for a combination gang consisting of a foreman, carpenters, handy men, and laborers will range from about $0.90 to $1.85.

Foremen will cost $1.50 to $3 per hour, and a good superintendent $2.50 to $5 per hour.

Labor Diagram.—The labor costs for forms are shown in Diagram 5-2 (page 571). The diagram may be used for determining the labor cost per square foot for form surface for any kind of work relating to forms, such as assembling, erecting, stripping, cleaning, and repair, or any combinations of these kinds of work. To use this diagram, the labor wage per hour and the labor-hours required per 100 sq. ft. of form surface must be known or assumed. For example, assume that the hourly

wage is $0.83 and that the labor-hours required to assemble, erect, strip, and clean the forms for 100 sq. ft. of form surface are 6.5. Then, from the diagram, the labor cost per square foot of form surface is $0.054.

5. Plant.—The plant used will depend on the size of the job and the equipment available. On comparatively small jobs, a few workbenches and the hand tools for the carpenters will be all the plant needed. On large jobs, sheds, more benches, power saws, etc., will be required in addition to the ordinary hand tools.

Plant costs will vary from a few cents per 100 sq. ft. of form surface, where benches only and no power saws or other equipment are provided, up to about $1, depending upon the amount of mechanical equipment provided and the total area of form surface. The use of power saws and other mechanical equipment will tend to reduce the labor costs.

6. Overhead and Profit.—Overhead costs, including labor insurance, social-security taxes, general supervision, engineering, and general office expense, will vary from 10 to 35 per cent of the total cost, with 15 per cent as an average value. When based on labor costs alone, overhead costs will vary from 20 to 50 per cent.

Profit on form work (when figured separately) will usually vary from 10 to 25 per cent.

7. Summary.—The total and unit costs of form work may be summarized as follows:

Item	Unit Costs per 100 Sq. Ft. or per Sq. Ft.	Total Costs
Materials..........................	$	$
Labor..............................		
Plant..............................		
Overhead...........................		
Profit.............................		
Total..............................	$	$

8. Metal Forms.—A variety of metal forms have been satisfactorily used for concrete work for some years. The first cost of a metal form varies considerably with the weight of metal used, design, shape, and cost of fabrication. Usually the first cost of a metal form is much greater than that of a wooden form. However, when the metal form is rugged and can be used and re-used many times (*i.e.*, many more times than a corresponding wooden

form), the cost per use may be reasonably low and may in some cases be less than the cost of wooden forms. When a metal form may be used many times, the cost per square foot of form surface may range from about $0.03 to $0.15.

The labor costs for erecting, cleaning, and stripping metal forms will usually be less than for assembling, erecting, stripping, and cleaning wooden forms that may be used for the same kind of concrete work. Assembling costs, if any, are usually included with the erection costs. The labor required for metal forms is shown in Table 5-4.

TABLE 5-4.—APPROXIMATE LABOR REQUIRED FOR METAL FORMS

Item	Labor-hours per 100 sq. ft. of form surface	Square feet of form surface per labor-hour
Erection (and assembling)	2– 6	17– 50
Strip and clean	1– 4	25–100
Minor repairs	1– 3	33–100
Total	4–13	8– 25

Diagram 5-2 may be used for estimating the labor costs of metal forms when the labor wage is known and the hourly output may be readily assumed.

In some cities, the metal-form work is let as a subcontract. The subcontractor supplies the forms and furnishes all the labor required for a complete job of forming.

In some localities, the general contractor or the concrete contractor may rent metal forms for use on any particular job. Rental prices vary considerably according to type and make of forms.

Because of the many varieties and designs of metal forms on the market, it is impractical in this text to give any estimates of the cost of metal forms.

9. **Illustrative Estimate for Wooden Forms.**—*Make a complete estimate of the cost for the following concrete forms, including the form lumber required in board feet, pounds of nails and bolts, labor in hours, and costs of each for the following form surfaces: foundations and footings 785 sq. ft., walls 2,180 sq. ft., columns 3,150 sq. ft., column heads 1,780 sq. ft., floors 14,200 sq. ft., beams 3,160 sq. ft., roofs 4,100 sq. ft. Take unit prices as follows: form lumber $90 per 1,000 ft. b.m. delivered at the job, bolts and*

nails \$0.06 per pound, 1 foreman at \$3 per hour, 3 carpenters at \$2 per hour, 3 handy men at \$1.50 per hour, and 3 laborers at \$1 per hour. Assume 15 per cent of total cost for overhead and 10 per cent for profit. Forms are to be made and erected and later stripped and cleaned. Assume salvage value of form lumber to be 50 per cent. (Some estimators use different salvage values for different forms.)

MATERIALS ESTIMATE

Item	Form surface, sq. ft.	Ft. b.m. per sq. ft. of form surface	Lumber, ft. b.m.
Foundations and footings	785	3.0	2,355
Walls	2,180	2.5	5,450
Columns	3,150	2.5	7,875
Column heads	1,780	3.0	5,340
Floors	14,200	2.3	32,660
Beams	3,160	5.0	15,800
Roofs	4,100	2.5	10,250
Total	29,355	...	79,730

About 80,000 ft. b.m. required.
The values for number of board feet per square foot of form surface are estimated for the several items, and represent fair average values.
Cost of form lumber less salvage value is \$90 × (1.00 − 0.50), or \$45 per 1,000 ft. b.m.

MATERIALS ESTIMATE USING DIAGRAM 5-1

Item	Form surface, sq. ft.	Ft. b.m. per sq. ft. of form surface	Cost per sq. ft. of form surface	Cost
Foundations and footings	785	3.0	\$0.135	\$ 106
Walls	2,180	2.5	0.110	240
Columns	3,150	2.5	0.110	347
Column heads	1,780	3.0	0.135	241
Floors	14,200	2.3	0.105	1,491
Beams	3,160	5.0	0.225	712
Roofs	4,100	2.5	0.110	451
Total for lumber	29,355	...	......	\$3,588
Add for nails and bolts, 2,350 lb. at \$0.06				\$ 141
Total for lumber, nails, and bolts				\$3,729

Lumber required = \$3,588 ÷ \$45 = 79,730 ft. b.m.

Cost of form lumber at \$45 per 1,000 ft. b.m. = \$45 × 79.730 = \$3,588
Cost of nails and bolts, etc., at 8 lb. per 100 sq. ft. of form surface
and \$0.06 per pound = \$0.06 × 8 × 294 = 141
Total cost (assuming 50 per cent salvage value) = \$3,729

If desired, the materials estimate may be prepared with the aid of Diagram 5-1. The cost of lumber per 1,000 ft. b.m. delivered at the job is \$90 less salvage value, or \$45. The cost per square foot of form surface is obtained from Diagram 5-1. Computations may be made by slide rule to the nearest dollar. This estimate may be tabulated as shown on page 124.

The labor estimate may be prepared as follows:

Item	Form surface, square feet	Labor-hours per 100 sq. ft. form surface		Total labor-hours	Labor costs
		Assemble and erect	Strip and clean		
Foundations and footings..	785	7	3	79	\$ 130
Walls....................	2,180	10	3	284	466
Columns..................	3,150	8	4	378	624
Column heads.............	1,780	12	4	285	470
Floors...................	14,200	7	3	1,420	2,344
Beams....................	3,160	10	4	443	730
Roofs....................	4,100	8	3	451	746
Total..................	29,355	..	..	3,340	\$5,510

Labor-hours per 100 sq. ft. of form surface are average values for the different kinds of form work.

Total wages per hour for the gang are

$$\$3 + \$2 \times 3 + \$1.50 \times 3 + \$1 \times 3,$$

or \$16.50. Average wage per hour is \$1.65. In computing this average wage, it is assumed that the presence and ability of the foreman to direct the work of the men will be at least equivalent to the work of one man.

Labor cost for forms is \$1.65 × 3,340 = \$5,510.

If desired, the labor estimate may be prepared with the aid of Diagram 5-2. The average wage assumed for the 10-men gang is \$1.65, as before. The estimate may be tabulated as shown at the top of page 126.

Labor-hours required = \$5,510 ÷ \$1.65 = 3,340 labor-hours.

In this illustrative estimate, the materials and labor estimates have each been prepared with and without the use of diagrams. A slide rule was used to reduce the time required for multiplication and division.

Item	Form surface, square feet	Labor-hours per 100 sq. ft. form surface*	Unit costs per sq. ft. of form surface†	Total labor costs
Foundations and footings..	785	10	$0.165	$ 130
Walls	2,180	13	0.215	469
Columns..................	3,150	12	0.200	630
Column heads.............	1.780	16	0.265	472
Floors...................	14,200	10	0.165	2,343
Beams....................	3,160	14	0.230	728
Roofs....................	4,100	11		
Total....................	29,355	..	......	$5,510

* Assemble, erect, strip, and clean.
† From Diagram 5-2.

Plant costs will be small and will be taken at about $0.30 per 100 sq. ft. of form surface, or about $88 for the job, assuming that very little mechanical equipment will be used.

Overhead costs will be 20 per cent of materials, labor, and plant, or 20 per cent of (3,729 + 5,510 + 88), or $1,866.

Profit will be 10 per cent of materials, labor, plant, and overhead, or 10 per cent of (3,729 + 5,510 + 88 + 1,866), or $1,120.

This estimate for forms may be summarized as follows:

Item	Foundations and footings	Walls	Columns	Column heads	Floors	Beams	Roofs	Total
Materials.....	$ 110	$ 250	$ 361	$ 251	$1,548	$ 740	$ 469	$ 3,729
Labor.........	130	469	630	472	2,343	728	738	5,510
Plant.........	2	6	10	5	43	10	12	88
Overhead.....	48	145	200	146	787	296	244	1,866
Profit.........	29	87	120	88	472	178	146	1,120
Total.........	$ 319	$ 957	$1,321	$ 962	$5,193	$1,952	$1,609	$12,313
Cost per 100 sq. ft........	$40.65	$43.85	$42.00	$54.00	$36.60	$61.75	$39.25	$42.00

B. ESTIMATING CONCRETE

10. Concrete Take-off.—The first step in preparing an estimate for concrete is to take-off or list all the quantities of con-

crete required for all the different parts of the work and for all the different mixes.

In preparing the list of concrete quantities, it is customary to use a sheet or page for each different mix, and to arrange the columns on each page in about the following order:

Description (footing, beam, etc.).

Dimensions (of each unit in feet).

Volume (cubic feet or cubic yards).

Other columns may be added for unit and total prices, etc.

In taking-off quantities of concrete, it is customary to begin at the bottom or one end of the structure and go over it systematically. In a concrete building, the order of take-off would be about as follows:

Footings.

Foundation walls.

Columns (interior and exterior). (Ordinary column caps and brackets are usually included with columns.)

Floor and roof slabs.

Drop panels.

Beams and girders (exterior and interior).

Exterior walls.

Partitions.

Window sills and copings.

Stairs.

Miscellaneous.

Sidewalks and drives.

11. Units of Measurement.—All concrete is usually measured net, as fixed or placed in the structure. Units of measurement are cubic yards or cubic feet, cubic yards being the common unit. No deductions are made for steel beams and reinforcement in the concrete unless the steel has a cross-sectional area of more than 1 sq. ft. No deductions are made for pipes or holes having a sectional area of less than 1 sq. ft. Each mix of concrete should be measured and described separately, and the concrete in different members of the structure should be measured and described separately according to location or purpose of the work.

Many rules are given for measuring stairs, but the best rule is to compute the quantity of concrete required in cubic yards or cubic feet by some simple method.

Sidewalks and pavements should be measured by the square foot or square yard with the thickness and mix stated so that the number of cubic yards or cubic feet of each mix may be easily computed.

The unit of measure for precast concrete work is usually the cubic foot.

Curbs, gutters, window sills, lintels, moldings, and such work are often measured per lineal foot, other dimensions being given so that the number of cubic yards or cubic feet may be found.

Concrete finishing is measured by the square foot or square yard of finished surface. When extra materials are required, as for a granolithic finish, the thickness of the extra surfacing or topping should be given.

12. Quantities of Materials.—After the take-off has been completed and the total yardage of each kind of concrete found, the quantities of cement and fine and coarse aggregates should be computed. The proportions of a concrete mix may be given by volume or by weight, and may be for aggregates that are surface dry or for aggregates containing some moisture as is usually the case on the job. At the present time, and especially on the larger jobs, the proportions of the mixes are nearly always given by weight.

In the proportioning and mixing of the concrete materials during construction, it is necessary to make allowances for the amounts of free water present in the aggregates. However, when estimating the quantities of materials required, it is not necessary to make allowance for free moisture except when the sand is moist and is measured by volume. The addition of a small percentage of free moisture to a sand will usually cause it to swell or bulk. For some sands, the bulking effect may be as much as 20 or 25 per cent, and often occurs with about 6 or 7 per cent of free moisture. When a sand bulks, its weight per cubic foot decreases. When a sand is placed in a container and inundated (completely covered with water), the bulking effect is negligible. Hence, when measuring sand by volume, it should be measured surface dry or inundated. When measured in moist condition, the bulking effect must be determined and allowed for.

13. Quantities Measured by Volume.—When the proportions of a mix are given by volume, the quantities required per

cubic foot or cubic yard may be approximately computed by the following formulas:

Let c, w, s, and g be the proportions by volume of cement, water, fine aggregate, and coarse aggregate, respectively. The proportion of cement c is usually taken as unity, and the fine aggregate is measured dry or inundated.

Quantities by volume for 1 cu. ft. of concrete:

Sacks of cement per cubic foot of concrete (To reduce sacks of cement to barrels, divide by 4.) $= \dfrac{1.67 \times c}{c + w + s + g}$

Gallons of water per cubic foot of concrete $= \dfrac{12.5 \times w}{c + w + s + g}$

Cubic feet of fine aggregate per cubic foot of concrete

$$= \frac{1.67 \times s}{c + w + s + g}$$

Cubic feet of coarse aggregate per cubic foot of concrete (To reduce cubic feet of aggregate to cubic yards, divide by 27.) $= \dfrac{1.67 \times g}{c + w + s + g}$

Quantities by volume for 1 cu. yd. of concrete:

Sacks of cement for cubic yards of concrete $= \dfrac{45 \times c}{c + w + s + g}$

Gallons of water per cubic yard of concrete $= \dfrac{340 \times w}{c + w + s + g}$

Cubic yards of fine aggregate per cubic yard of concrete

$$= \frac{1.67 \times s}{c + w + s + g}$$

Cubic yards of coarse aggregate per cubic yard of concrete

$$= \frac{1.67 \times g}{c + w + s + g}$$

When proportioning by volume, the amount of water is usually given as gallons of water per sack of cement. The water may be measured in a tank calibrated to read to the nearest tenth or quarter of a gallon. One U. S. gallon of water contains 231 cu. in., and there are approximately 7.5 gal. per cubic foot.

Table 5-5 gives approximate quantities of materials required for 1 cu. yd. of concrete for some of the more common mixes.

14. Quantities Measured by Weight.—The computations required when proportioning by weight are quite simple. For example, in a 1-3-6 mix by weight there would be 1 lb. of cement

TABLE 5-5.—APPROXIMATE VOLUMES OF MATERIALS REQUIRED FOR 1 CU. YD. OF CONCRETE*

Proportions by volume with surface dry aggregate

Consistency	Proportions		Materials for 1 cu. yd. concrete					
	With gravel $c + s + g + w$	With stone $c + s + g + w$	Cement, sacks	Water, gal.	With gravel		With stone	
					Sand, cu. yd.	Gravel, cu. yd.	Sand, cu. yd.	Stone, cu. yd.
One-inch Aggregate								
Water = 5 gal. per sack of cement. 28-day strength = 4,500 lb. per sq. in.								
Stiff	1 + 2.1 + 3.1 + 0.67	1 + 2.5 + 2.8 + 0.67	6.6	33	0.52	0.76	0.62	0.67
Medium	1 + 1.9 + 2.7 + 0.67	1 + 2.2 + 2.4 + 0.67	7.2	36	0.50	0.73	0.59	0.65
Wet	1 + 1.7 + 2.4 + 0.67	1 + 2.0 + 2.2 + 0.67	7.8	39	0.49	0.70	0.57	0.63
Water = 6 gal. per sack of cement. 28-day-strength = 3,500 lb. per sq. in.								
Stiff	1 + 2.8 + 3.6 + 0.8	1 + 3.3 + 3.2 + 0.8	5.5	33	0.58	0.74	0.68	0.66
Medium	1 + 2.5 + 3.2 + 0.8	1 + 3.0 + 2.9 + 0.8	6.0	36	0.56	0.72	0.66	0.64
Wet	1 + 2.3 + 2.9 + 0.8	1 + 2.6 + 2.6 + 0.8	6.5	39	0.54	0.70	0.64	0.62
Water = 7.5 gal. per sack of cement. 28-day strength = 2,500 lb. per sq. in.								
Stiff	1 + 3.9 + 4.5 + 1	1 + 4.6 + 3.9 + 1	4.4	33	0.64	0.73	0.74	0.64
Medium	1 + 3.5 + 4.0 + 1	1 + 4.1 + 3.5 + 1	4.8	36	0.62	0.70	0.72	0.62
Wet	1 + 3.1 + 3.5 + 1	1 + 3.6 + 3.1 + 1	5.2	39	0.60	0.68	0.70	0.60
Two-inch Aggregate								
Water = 5 gal. per sack of cement. 28-day strength = 4,500 lb. per sq. in.								
Stiff	1 + 2.2 + 3.7 + 0.67	1 + 2.6 + 3.4 + 0.67	6.0	30	0.49	0.82	0.58	0.75
Medium	1 + 2.0 + 3.2 + 0.67	1 + 2.3 + 3.0 + 0.67	6.6	33	0.48	0.79	0.56	0.72
Wet	1 + 1.7 + 2.9 + 0.67	1 + 2.0 + 2.6 + 0.67	7.2	36	0.46	0.76	0.54	0.70
Water = 6 gal. per sack of cement. 28-day strength = 3,500 lb. per sq. in.								
Stiff	1 + 3.0 + 4.3 + 0.8	1 + 3.4 + 4.0 + 0.8	5.0	30	0.55	0.80	0.64	0.73
Medium	1 + 2.6 + 3.8 + 0.8	1 + 3.0 + 3.5 + 0.8	5.5	33	0.53	0.78	0.62	0.70
Wet	1 + 2.3 + 3.4 + 0.8	1 + 2.7 + 3.1 + 0.8	6.0	36	0.52	0.76	0.60	0.68
Water = 7.5 gal. per sack of cement. 28-day strength = 2,500 lb. per sq. in.								
Stiff	1 + 4.1 + 5.3 + 1	1 + 4.7 + 4.8 + 1	4.0	30	0.61	0.79	0.70	0.71
Medium	1 + 3.6 + 4.6 + 1	1 + 4.2 + 4.2 + 1	4.4	33	0.59	0.76	0.68	0.69
Wet	1 + 3.2 + 4.2 + 1	1 + 3.7 + 3.8 + 1	4.8	36	0.58	0.74	0.66	0.67

* Values in table are taken from publications of the Portland Cement Association.

The reader is referred to this association for further information on the proportions, design, and control of concrete mixtures.

for every 3 lb. of fine aggregate and every 6 lb. of coarse aggregate.

The following rule-of-thumb formulas may be used for computing the approximate weights of cement, fine and coarse aggregates.

Let c', w', s', and g' be the proportions by weight of cement, water, fine aggregate, and coarse aggregate, respectively. The proportion of cement c' is usually taken as unity. Aggregates are often sold by the short ton of 2,000 lb.

For 1 cu. ft. of concrete, assume weight to be 150 lb.

$$\text{Pounds of cement per cubic foot of concrete} = \frac{150 \times c'}{c' + w' + s' + g'}$$

$$\text{Sacks of cement per cubic foot of concrete} = \frac{1.6 \times c'}{c' + w' + s' + g'}$$

$$\text{Pounds of water per cubic foot of concrete} = \frac{150 \times w'}{c' + w' + s' + g'}$$

Pounds of fine aggregate per cubic foot of concrete

$$= \frac{150 \times s'}{c' + w' + s' + g'}$$

Pounds of coarse aggregate per cubic foot of concrete

$$= \frac{150 \times g'}{c' + w' + s' + g'}$$

For 1 cu. yd. of concrete, assumed to weigh 4,000 lb.

$$\text{Pounds of cement per cubic yard of concrete} = \frac{4{,}000 \times c'}{c' + w' + s' + g'}$$

$$\text{Sacks of cement per cubic yard of concrete} = \frac{42.5 \times c'}{c' + w' + s' + g'}$$

$$\text{Pounds of water per cubic yard of concrete} = \frac{4{,}000 \times w'}{c' + w' + s' + g'}$$

Tons of fine aggregate per cubic yard of concrete

$$= \frac{2s'}{c' + w' + s' + g'}$$

Tons of coarse aggregate per cubic yard of concrete

$$= \frac{2g'}{c' + w' + s' + g'}$$

The water is usually weighed when proportioning by weight. The amount of water may be given as pounds of water per 100 lb. of cement or pounds of water per sack of cement. One U. S. gallon of water weighs about 8.35 lb.

TABLE 5-6.—APPROXIMATE WEIGHTS OF MATERIALS REQUIRED FOR 1 CU. YD. OF CONCRETE*

Proportions by weight with surface-dry aggregate

Consistency	Proportions		Materials for 1 cu. yd.					
	With gravel $c' + s' + g' + w'$	With stone $c' + s' + g' + w'$	Cement, sack	Water, gal.	With gravel		With stone	
					Sand, tons	Gravel, tons	Sand, tons	Gravel, tons
One-inch Aggregate								
Water = 5 gal. per sack of cement. 28-day strength = 4,500 lb. per sq. in.								
Stiff	1 + 2.0 + 3.3 + 0.44	1 + 2.4 + 2.9 + 0.44	6.6	33	0.63	1.01	0.74	0.90
Medium	1 + 1.8 + 2.9 + 0.44	1 + 2.1 + 2.6 + 0.44	7.2	36	0.60	0.98	0.72	0.87
Wet	1 + 1.6 + 2.6 + 0.44	1 + 1.9 + 2.3 + 0.44	7.8	39	0.58	0.94	0.79	0.84
Water = 6 gal. per sack of cement. 28-day strength = 3,500 lb. per sq. in.								
Stiff	1 + 2.7 + 3.8 + 0.53	1 + 3.2 + 3.4 + 0.53	5.5	33	0.70	0.99	0.82	0.88
Medium	1 + 2.4 + 3.4 + 0.53	1 + 2.8 + 3.0 + 0.53	6.0	36	0.68	0.96	0.79	0.85
Wet	1 + 2.1 + 3.1 + 0.53	1 + 2.5 + 2.7 + 0.53	6.5	39	0.66	0.93	0.77	0.82
Water = 7.5 gal. per sack of cement. 28-day strength = 2,500 lb. per sq. in.								
Stiff	1 + 3.7 + 4.7 + 0.67	1 + 4.3 + 4.1 + 0.67	4.4	33	0.77	0.97	0.90	0.85
Medium	1 + 3.3 + 4.2 + 0.67	1 + 3.9 + 3.7 + 0.67	4.8	36	0.75	0.94	0.87	0.83
Wet	1 + 3.0 + 3.7 + 0.67	1 + 3.4 + 3.3 + 0.67	5.2	39	0.73	0.91	0.84	0.80
Two-inch Aggregate								
Water = 5 gal. per sack of cement. 28-day strength = 4,500 lb. per sq. in.								
Stiff	1 + 2.1 + 3.9 + 0.44	1 + 2.5 + 3.5 + 0.44	6.0	30	0.60	1.10	0.70	1.00
Medium	1 + 1.9 + 3.4 + 0.44	1 + 2.2 + 3.1 + 0.44	6.6	33	0.58	1.06	0.68	0.95
Wet	1 + 1.7 + 3.0 + 0.44	1 + 1.9 + 2.8 + 0.44	7.2	36	0.56	1.02	0.65	0.93
Water = 6 gal. per sack of cement. 28-day strength = 3,500 lb. per sq. in.								
Stiff	1 + 2.8 + 4.6 + 0.53	1 + 3.3 + 4.2 + 0.53	5.0	30	0.67	1.07	0.77	0.97
Medium	1 + 2.5 + 4.0 + 0.53	1 + 2.9 + 3.6 + 0.53	5.5	33	0.65	1.04	0.75	0.94
Wet	1 + 2.2 + 3.6 + 0.53	1 + 2.6 + 3.2 + 0.53	6.0	36	0.63	1.01	0.73	0.91
Water = 7.5 gal. per sack of cement. 28-day strength = 2,500 lb. per sq. in.								
Stiff	1 + 3.9 + 5.6 + 0.67	1 + 4.5 + 5.0 + 0.67	4.0	30	0.74	1.05	0.85	0.95
Medium	1 + 3.5 + 4.9 + 0.67	1 + 4.0 + 4.5 + 0.67	4.4	33	0.72	1.02	0.83	0.92
Wet	1 + 3.1 + 4.4 + 0.67	1 + 3.5 + 4.0 + 0.67	4.8	36	0.70	0.99	0.80	0.89

* Values in this table are taken from publications of the Portland Cement Association.

Table 5-6 gives approximate weights of materials required for 1 cu. yd. of concrete.

On some jobs, the U. S. gallons of water per sack of cement and the slump or consistency may be given, and the estimator must then estimate the proportions of the mix as well as compute the quantities. On other jobs, only the strength (28-day compression) may be given with or without the slump, and the estimator must estimate the proportions and compute the quantities. The slump for most concrete work will be about as follows:

Table 5-7

Type of Concrete	Slump, Inches
Mass concrete (stiff mix)	2–3
Pavements, machine finished (very stiff mix)	1
Pavements, hand finished (stiff mix)	2–4
Reinforced concrete, thin vertical sections (medium mix)	4–7
Reinforced concrete, columns (medium mix)	4–7
Reinforced concrete, thin confined horizontal sections (wet mix)	6–9
Reinforced concrete, heavy sections (stiff mix)	2–4

The amount of water required will vary from 9 to 15 gal. per sack of cement, or from 30 to 150 gal. per cubic yard of concrete, depending upon the water-cement ratio and the water used for washing the mixer and other equipment and the wastage. About 100 gal. of water per cubic yard of concrete is a good value for estimating purposes.

15. Quantities by Weight by Absolute-volume Method.—For a more accurate method of computing weights of concrete materials, the absolute volume method is recommended. The proportions of cement, fine aggregate, coarse aggregate, and water are given by weight. Then the amount of concrete in cubic feet

Table 5-8

Material	Apparent specific gravity	Solid weight per cubic foot
Water (fluid weight)	1.00	62.4
Portland cement	3.10	193.5
Average sand	2.65	165.5
Average gravel or coarse aggregate	2.65	165.5

made by, say, one sack of cement and the other materials is computed. After that, the weights of the materials per cubic yard are computed. The apparent specific gravities and solid weights per cubic foot may be taken as follows for the purpose of estimating:

Actual apparent specific gravities must be used for special aggregates such as blast-furnace slag and cinders.

16. Illustrative Problem.—For an example of the absolute-volume method, assume that the weights of materials per cubic yard of concrete are required for a 1 to 2.20 to 3.30 mix by weight with 6.5 U. S. gal. of water per sack of cement. Assume surface dry aggregates.

Solution: First compute the cubic feet of concrete made by a one-sack batch.

Cement, 1 sack of 94 lb.,	$\frac{94}{193.5}$	= 0.485 cu. ft.
Sand,	$\frac{94 \times 2.20}{165.5}$	= 1.250 cu. ft.
Gravel,	$\frac{94 \times 3.30}{165.5}$	= 1.875 cu. ft.
Water, 6.5 gal.	$\frac{6.5 \times 8.35}{62.4}$	= 0.870 cu. ft.
Absolute volume of a one-sack batch		= 4.480 cu. ft.

That is, one sack of cement with the correct proportions of sand, gravel, and water will produce 4.48 cu. ft. of concrete, assuming no absorption or losses in manufacture.

Quantities required per cubic yard of concrete are

Cement $= \frac{27}{4.48} = 6.03$ sacks $= 1.51$ bbl. $= 567$ lb.
Sand $= 6.03 \times 94 \times 2.20 = 1{,}250$ lb. $= 0.625$ ton
Gravel $= 6.03 \times 94 \times 3.30 = 1{,}870$ lb. $= 0.935$ ton
Water $= 6.03 \times 6.5 \times 8.35 = 327$ lb. $= 39.2$ U.S. gal.

Total weight per cubic yard = 4,014 lb., assuming no air voids

Simplified Solution: A variation of this method is to assume that 1 cu. yd. of concrete, made with average aggregates having an apparent specific gravity of 2.65, weighs 4,000 lb.

Then, a one-sack batch of a 1 to 2.2 to 3.3 mix by weight with 6.5 U. S. gal. per sack will give

$$94 + (6.5 \times 8.35 = 54) + (94 \times 2.2 = 207) + (94 \times 3.3 = 310),$$

or 665 lb. of concrete.

Quantities required per cubic yard are

Cement $= 4{,}000 \div 665 = 6.02$ sacks $= 566$ lb.
Sand $= 566 \times 2.2 = 1{,}245$ lb., or 0.623 ton
Gravel $= 566 \times 3.3 = 1{,}870$ lb., or 0.935 ton
Water $= 6.02 \times 6.5 \times 8.35 = 326$ lb., or 39.1 U. S. gal.

Total weight per cubic yard (as a check) = 4,007 lb.
These results agree very closely with those previously obtained.

17. Costs of Materials.—The cost of cement delivered on the job is generally used, though on very large jobs the cost of cement will be the price at the mill plus costs of freight, unloading, trucking to job, storing, inspection and testing, and loss due to waste and spoiling. Prices may be quoted per barrel for cement in cloth bags, paper bags, or bulk. Mill prices are sometimes quoted for cement in bulk or bagged with prices of bags extra. Cloth bags cost \$0.40 per barrel and paper bags \$0.20 per barrel. Paper bags are not returnable. From the cost of cement in cloth bags, there should be deducted \$0.10. for each good cloth sack returned to the mill or dealer. As a general rule, about 10 per cent of the cloth bags will be wasted. Quotations of prices usually given by cement companies are for the cost of cement in carload lots f.o.b. cars at the station near which the job is located. To this price must be added the cost of testing, unloading, and trucking. Average cost of cement (without bags) will be \$2 to \$3 per barrel for large quantities, or \$0.50 to \$0.75 per sack. Prices are higher for quantities less than carload lots.

Table 5-9 shows how the cost of cement at the job may be computed. For an example, the cost of cement f.o.b. cars at the railway station is assumed to be \$2.60 per barrel or \$0.65 per sack.

TABLE 5-9.—COST OF CEMENT AT JOB SITE

Item	Per sack	Per barrel
Cement f.o.b. cars	\$0.65	\$2.60
Cotton bags	0.10	0.40
Testing	0.01	0.04
Unloading, trucking, and storing about	0.05	0.20
Total	\$0.81	\$3.24
Credit for bags returned less loss and freight	0.09	0.36
Net cost of cement at job	\$0.72	\$2.88

Diagram 5-3 (page 572) may be used for determining the cost of cement per cubic yard of concrete when the number of sacks per cubic yard and the price per sack at the job are known.

The cost of sand, gravel, and crushed rock at the job will vary greatly in different localities. Prices may be given per cubic yard or per short ton f.o.b. cars at station nearest the job, or per cubic yard or per short ton delivered at the job. The following are approximate prices only, and for relatively large quantities such as carload lots or greater.

TABLE 5-10.—COST OF AGGREGATE AT JOB SITE

Material	Weight per cubic yard, pounds	*Price per ton*	*Price per cubic yard*
Sand	2,400–3,000	$1.25–$3.00	$1.70–$4.00
Gravel	2,300–3,000	1.40– 3.25	1.90– 4.25
Crushed stone	2,200–2,700	1.75– 3.50	2.20– 4.50

TABLE 5-11.—APPROXIMATE LABOR REQUIRED FOR MIXING, PLACING, AND CURING CONCRETE

Kind of work	Labor-hours per cubic yard
Hand mixing	1– 2
Machine mixing	0.5– 1.2
Machine mixing plus heating of water and aggregate	0.7– 1.5
Placing in footings and abutments	1– 4
Placing in columns and thin walls	2– 5
Placing in thick walls	1– 4
Placing in floors and slabs	1– 4
Placing in stairs	3– 6
Placing structural concrete (average)	1– 4
Placing structural concrete in cold weather	2– 5
Curing concrete in ordinary or warm weather	0.5– 1
Curing concrete in cold weather including installation, maintenance, and removal of protective enclosures, and heating	1– 5
Mix, place, and cure, ordinary weather	2– 6
Mix, place, and cure, cold weather	3–10

operator and other skilled labor at $1 to $2 per hour, and ordinary labor at $0.65 to $1.25 per hour, the average cost of labor for mixing, placing, and curing 1 cu. yd. of concrete will vary from about $3 to $7.

Diagram 5-6 (page 575) may be used for determining the cost of labor per cubic yard of concrete when the hours of labor required for mixing, placing, and curing 1 cu. yd. of concrete and the average hourly wage are known or may be readily assumed.

19. Plant.—The plant required for a structural concrete job will vary (usually with the size of the job) from a smaller mixer with a few wheelbarrows, shovels, hand tools, runways, etc., to a large mixer with weighing devices and cranes or derricks with buckets, cableway and buckets, belt conveyors, concrete pumping equipment, or hoists with carts and runways. Equipment is needed for weighing, mixing, transporting, placing, and sometimes finishing (as for concrete floors) and for curing the concrete.

The equipment needed for curing concrete in warm weather will include hose and a water supply and perhaps canvas, burlap, straw, etc., for covering the surface of the concrete to assist in

keeping the concrete surface from drying out. All the concreting plant may be located at the job, or the proportioning plant may be in another location. Sometimes ready-mixed concrete is purchased delivered at the job.

For cold-weather concreting, some equipment must be provided for heating the aggregates and water. This equipment may be quite simple, such as a tank for the water with a place for a fire or a firebox beneath it, and a corrugated iron pipe over which the aggregate is piled and in which a coal or wood fire is built. Perhaps a more satisfactory heating plant would be a steam boiler furnishing steam to pipe coils in the water tank and to steam pipes in the piles of aggregate.

The plant required for curing concrete in cold weather will include materials for enclosing and protecting the concrete, and provision for heating during the curing period. Materials for enclosing and protecting the concrete may be canvas, burlap, straw, etc. The forms may be warmed by means of a hose and live steam from a boiler. The heating may be done by steam pipes or by salamanders. One salamander is required for about every 300 sq. ft. of floor area. In addition, one or two extra salamanders may be required for each exterior column, depending upon the weather and wind. If a steam boiler is used, at least a 50-hp. boiler should be provided, *i.e.*, licensed to carry a pressure of at least 80 lb. per square inch. The curing time may vary from about 4 to 8 days. The reader is referred to publications of the Portland Cement Association for information on making, placing and curing concrete in cold weather.

Mixers are usually rated according to the approximate number of cubic feet in one batch. Capacities of mixers used in construction work vary from about 3½ cu. ft. to 3 or 4 cu. yd. or more. The mixers are often designated as 10S, 28S, 56E, the number denoting capacity in cubic feet, the letter S denotes side dump common to construction mixers, and the letter E denotes end dump common to paving mixers. For example, 28S means a side-dump mixer of 28 cu. ft. (or 1 cu. yd.) capacity. The mixing cycle of a batch mixed includes charging the mixer, mixing the concrete, and discharging the concrete. The minimum time per batch is about 3 min., with 4 to 5 min. as an average. The minimum mixing time is 1 min., and frequently 1½ or more minutes are specified.

equipment used, the fuel burned, and the temperature. If desired, plant costs for cold-weather curing may be divided into costs of equipment and costs of plant material used. The equipment will include the boiler, pipes, hose, heaters, salamanders, burlap, and canvas that may be used on many jobs. The plant materials will include water, sand, straw, and fuel that are used up or consumed on the job.

Plant costs per cubic yard of concrete may range about as given in Table 5-12. These values are approximate.

Diagram 5-7 (page 576) may be used for determining the plant cost per cubic yard of concrete when the output and hourly costs of the plant are known or can be assumed.

20. Overhead and Profit.—Overhead costs for mixing and placing concrete include such items as are usually included under this heading, such as general office expenses, labor and other insurance, superintendent, timekeeper, telephones, stationery, night watchman, and sundries. The cost of a foreman is usually included in the labor costs.

When based on total costs of materials, labor, and plant, the overhead will range from about 10 to 35 per cent. When based on labor costs alone, the overhead may range from 20 to 50 per cent.

When the mixing and placing of the concrete is considered as a separate job, a reasonable amount of profit should be allowed. The percentage of profit may vary from about 5 to 15 per cent of the costs of materials, labor, plant, and overhead.

21. Summary.—The unit and total costs of each class or mix of concrete may be summarized as follows:

Item	Class *A*		Class *B*		Etc.
	Cost per cu. yd.	Total cost	Cost per cu. yd.	Total cost	
Materials......	$	$	$	$	
Labor.........					
Plant.........					
Overhead......					
Profit.........					
Total.........					

22. Illustrative Estimate on Concrete.—Using the unit-quantity method, make a complete cost estimate for 1.650 cu. yd. of concrete, given the following:

Mix is 1 to 2.3 to 3.6 by weight, with 6.5 U. S. gal. of water per sack of cement.

Cost of cement per sack at job	\$0.71
Cost of sand per ton at job	\$1.65
Cost of gravel per ton at job	\$1.75
Cost of water per 1.000 gal	\$0.12
Cost of plant per cubic yard of concrete	\$2.05
Average wage of labor per hour	\$1.32
Labor-hours per cubic yard of concrete	4.40 hr.
Overhead expense. based on materials, labor, and plant	25 per cent
Profit, based on materials, labor, plant, and overhead	10 per cent

Quantities of materials required per cubic yard will be computed first. using the absolute-volume method and assuming average aggregates and a concrete weighing 4.000 lb. per cubic yard.

Assuming a one-sack batch,

Cement		= 94 lb.
Water	= 6.5 U. S. gal. × 8.35	= 54 lb.
Sand	= 94 × 2.3	= 216 lb.
Gravel	= 94 × 3.6	= 338 lb.
Total weight for a one-sack batch		= 702 lb.

Quantities per cubic yard of concrete:

Cement	= 4,000 ÷ 702	= 5.70 sacks	= 536 lb.
Water	= 5.70 × 6.5	= 37.00 U. S. gal.	= 309 lb.
Sand	= 536 × 2.3 ÷ 2,000	= 0.617 tons	= 1,233 lb.
Gravel	= 536 × 3.6 ÷ 2,000	= 0.965 tons	= 1,930 lb.
Total (for a check)			= 4,008 lb.

Summary of quantities and costs

	1 Cu. Yd.		1,650 Cu. Yd.	
Materials, using Diagrams 5-3 and 5-5:				
Cement	5.70 sacks	\$4.05	9.400 sacks	\$ 6,675
Water (including waste)	100 gal.	0.01	165.000 gal.	20
Sand	0.617 tons	1.02	1.020 tons	1,685
Gravel	0.965 tons	1.69	1.590 tons	2,790
Material costs		\$6.77		\$11,170
Labor, using Diagram 5-6, 4.40 hr		5.80	7,260 hr	9,570
Plant		2.05		3,385
Overhead, 16 per cent of materials, labor, plant		3.655		6,030
Profit, 8 per cent of materials, labor, plant, overhead		1.83		3,015
Total estimate		\$20.105		\$33,170

C. ESTIMATING REINFORCEMENT

23. Quantities of Materials.—Steel for reinforcement should be estimated in pounds, assuming that a square bar 1 by 1 by 12 in. long weighs 3.4 lb. In the take-off, reinforcing bars should be listed with reference as to whether they are plain bars, deformed bars, spirals, round or square bars of different diameters, bent bars, or straight bars, and also with reference to the places where they are to be used. Chairs, ties, pipe sleeves, clamps, units, threaded ends, turnbuckles, etc., should be tabulated separately. Wire cloth, expanded metal, and similar steel fabric sold by the roll or sheet should be measured and described by the square foot, stating size of mesh and weight per square foot. No allowances should be made for waste and cutting unless the cutting is done at the job. Allowances must be made for laps and splices when called for in the plans and specifications.

The take-off sheet for reinforcing steel should have columns for size of bar, number of pieces, length, and bends. The summary sheet should give size of bar, weight per lineal foot, total weight, bends, unit price, and total price. Separate sheets should be prepared for plain and deformed bars, spirals, stirrups, and for accessories, such as chairs, ties, and clamps.

The standard sizes of reinforcing bars are ¼ in. plain round and both plain and deformed bars of the following sizes: ⅜ in. round, ½ in. round, ½ in. square, ⅝ in. round, ¾ in. round, ⅞ in. round, 1 in. round, 1 in. square, 1⅛ in. square, and 1¼ in. square. Reinforcing bars of other sizes are "specials" and are hard to obtain.

Table 5-13 gives the sizes, cross-sectional areas, and weights in pounds per foot of length for various bars.

Steel bars for reinforcement may be purchased from the mill where they are rolled, from a main warehouse, or from a local warehouse. Bars purchased at the mill or at a main warehouse are cut to length, bundled, and tied. Bars purchased at a local warehouse must be bought from lengths in stock and then cut to the correct lengths at the job. Consequently, when time permits, the bars should be purchased from the mill to avoid cutting and waste. However, if the time is short or if the amount of steel is small, it may be advisable to buy the bars from a local warehouse.

TABLE 5-13.—SIZES, AREAS, AND WEIGHTS OF BARS

Size of bar, in.	Round bars		Square bars	
	Area, sq. in.	Weight, lb. per ft.	Area, sq. in.	Weight, lb. per ft.
¼	0.049	0.167	0.0625	0.213
⅜	0.110	0.376	0.141	0.478
½	0.196	0.67	0.250	0.85
⅝	0.307	1.04	0.391	1.33
¾	0.442	1.50	0.562	1.91
⅞	0.601	2.04	0.766	2.60
1	0.785	2.67	1.000	3.40
1⅛	0.994	3.38	1.266	4.30
1¼	1.227	4.17	1.562	5.31
1⅜	1.485	5.05	1.891	6.43
1½	1.767	6.01	2.250	7.65

24. Costs of Materials.—The price of steel varies considerably from time to time and, consequently, must be checked about each time that an estimate is made. The price depends upon the quantity in pounds purchased, the sizes of the bars, and the number of bends and hooks. The *base* price is the price quoted on bars ¾ to 1¼ in. in size f.o.b. the mill or main warehouse, and for quantities of 30,000 lb. or more. Extra prices are charged for quantities less than 30,000 lb., for sizes less than ¾ in., for bends made, and for engineering services. In addition, freight must be paid from mill to the city in which the job is located, and a truck delivery charge paid for delivering the bars from the railway station to the job. Hence, the price charged for bars of any size is composed of the sum of base price, quantity extras, size extras, bending extras, milling extras, engineering extras, freight charges, and delivery charges.

The *base* price is the price per 100 lb. of reinforcing bars f.o.b. mill or main warehouse, and includes cutting to specified lengths, bundling, and tagging. In December, 1946, base prices at Chicago and other basing points, except Gulf ports and Pacific ports, were $2.35 per 100 lb. for new billet steel bars and $2.35 per 100 lb. for rail steel bars.

In regard to chairs, spacers, ties, etc., the total cost of these will vary greatly, depending on the kind used and the number

required. An allowance of \$0.20 to \$0.50 for 100 lb. of reinforcing bars is usually satisfactory.

Quantity Extras per 100 Lb.	
30,000 lb. or more	None
10,000–30,000 lb	\$0.15
2,000–10,000 lb	\$0.25
Less than 2,000 lb	\$0.50
Size Extras per 100 Lb.	
¾ in. round and larger, plain or deformed	None
⅝ in. round, plain or deformed	\$0.10
½ in. round or square, plain or deformed	\$0.20
⅜ in. round, plain or deformed	\$0.40
¼ in. round, plain only	\$1.00
Bending Extras per 100 Lb.	
½ in. and larger, bent at not more than 6 points	\$0.40
½ in. and larger, bent at more than 6 points	\$0.90
All ¼ in. and ⅜ in., any number of bends	\$0.90
All stirrups and column ties	\$0.90
Milling Extras per 100 Lb.	
Removing burrs, etc., from ends of bars	
Bars over 4 ft. in length	\$0.20
2 to 4 ft. in length	\$0.30
Engineering Extras per 100 Lb.	
Listing	No charge
Detailing, and making of placing plans from designs prepared by others.	
Less than 15 tons, maximum charge of \$60	\$0.25
15–100 tons, maximum charge of \$300	\$0.20
100–200 tons, maximum charge of \$500	\$0.15
200 to 500 tons, maximum charge of \$1,000	\$0.125
Over 500 tons, no maximum charge	\$0.10
Designing .... detailing extras +	\$0.20
Freight per 100 Lb.	
Actual freight charge (car load or less than car load lots) from mill or main warehouse to destination	Actual freight
Delivery per 100 Lb.	
Delivery by truck from local warehouse or station to job site not less than	\$0.05

25. Labor Quantities and Costs.—The labor required will depend upon the amount of cutting and bending to be done at the job, upon the difficulty of placing the bars in the forms, and also upon the sizes and lengths of the different bars and the number of stirrups and column ties.

Cutting to specified length is usually done by the manufacturer, and consequently, only a little cutting, if any, will have

to be done at the job. The time required for cutting will usually range from 1 to 3 hr. per hundred cuts depending on bar sizes, tools available, and workmen. If the bars must be sawed, the labor will be increased greatly.

The time in hours required for making 100 bends or 100 standard hooks is given in Table 5-14.

TABLE 5-14.—LABOR-HOURS REQUIRED FOR MAKING 100 BENDS OR 100 HOOKS

Size of bar, inches	By hand		By machine	
	Bends, hours	Hooks, hours	Bends, hours	Hooks, hours
½ or less	2–4	3– 6	0.8–1.5	1.2–2.5
⅝, ¾, and ⅞	2.5–5	4– 8	1.0–2.0	1.6–3.0
1 and 1⅛	3–6	5–10	1.2–2.5	2.0–4.0
1¼ and 1½	4–7	6–12	1.5–3.0	2.5–5.0

The time required for placing 100 bars is given in Table 5-15. This time includes placing chairs and spacers; placing bars, stirrups, and spirals; and wiring in position.

TABLE 5-15.—LABOR-HOURS REQUIRED FOR PLACING 100 BARS

Size of bar, inches	Length of bar, feet		
	Under 10	10–20	20–30
	Labor-hours per 100 bars		
½ or less	3.5–6.0	5.0– 7.0	6.0– 8.0
⅝, ¾, and ⅞	4.5–7.0	6.0– 8.5	7.0– 9.5
1 and 1⅛	5.5–8.0	7.0–10.0	8.5–11.5
1¼ and 1½	6.5–9.0	8.0–12.0	10.0–14.0

The bending and placing of steel reinforcement bars may be done by handy men, at an hourly wage of $0.90 to $1.50, under the direction of a competent foreman (wage $1.50 to $3 per hour). In localities where union rules require a certain class of laborers, the wages of the laborers will probably range from $1.50 to $2 per hour.

If the reinforcement has to be piled or repiled at the job, an allowance of $0.05 per 100 lb. is usually enough to cover the cost of each piling or repiling. A laborer can pile or repile 1,000 to 2,000 ft. per hour, or about 2,000 to 4,000 lb. per hour.

Diagram 5-8 (page 577) gives the labor costs for making bends and hooks, and Diagram 5-9 (page 578) gives the labor costs for placing reinforcement bars.

26. Plant.—When the cutting and bending is done by the manufacturer, the plant required by the contractor is very little. Only hand tools will be required for placing and tieing. The cost of these tools should range from about $0.01 to $0.03 per 100 lb. of bars.

If the cutting and bending are to be done at the job, the contractor will need hand or power shears for cutting and one or more hand benders (depending on size of job) and perhaps a power bender also. Plant costs for cutting should range from $0.01 to $0.03 per 100 cuts, depending upon the particular job. Plant costs for bending with hand machines may vary from $0.003 to $0.02 per 100 bends. For bending with power machines, the plant costs per 100 bends will be about the same, as the power bender is faster though more costly to buy and operate. Trucking costs to and from the job will be extra and should be allowed for.

27. Overhead and Profit.—Overhead charges for bending and placing reinforcement are usually based on labor costs and will range from about 15 to 40 per cent when all such expenses as general supervision, timekeeping, pay roll, compensation and liability insurance, and social-security tax are included. In some instances on reinforced concrete work, overhead expenses are charged to the job as a whole and not apportioned to forms, concrete, and reinforcement.

On a reinforced concrete job, profit is often estimated on the job as a whole and is not apportioned to the several parts of the job. However, if the reinforcement is to be considered as a complete unit by itself, then an allowance should be made for profit.

28. Summary.—The complete estimate for the reinforcement on a reinforced concrete job would include costs of materials, labor, plant, overhead, and profit (if not otherwise apportioned). This summary may be tabulated as follows:

Item	Unit Cost per 100 Lb.	Unit Cost per ton	Total Cost
Materials . . .	$	$	$
Labor .			
Plant			
Overhead .			
Profit . . .			
Total.	$	$	$

29. Illustrative Estimate on Reinforcement.—Make a complete cost estimate of the reinforcement in place for the bars listed in the following table. Compute the weights and costs of the steel delivered at the job, assuming a base price of \$2.60 per 100 lb. and a freight rate of \$0.25 per 100 lb. Allow \$0.30 per 100 lb. of bars for chairs, spacers, and ties. Steel will be cut to length by the manufacturer, but all bends and hooks will be made at the job.

On most jobs, the manufacturer will cut the bars to specified length and make all bends and hooks. He will also make all bends and hooks for stirrups, and will make all column spirals and attach these spirals to spacers. It is usually advisable to have as much work as is practical done by the manufacturer, so that the work at the job will be less.

Consider extras for quantities and sizes and truck delivery as previously given. There will be no extras for bending and for engineering services.

All work is to be done by a gang of 1 foreman (\$1.30 per hour) and 3 handy men (\$0.70 per hour each). (December, 1946, wages are about 55 per cent more.

Allow 31 per cent of labor cost for overhead and 9 per cent of all costs for profit.

Compute the total cost of steel placed in the forms. Also compute cost of steel per 100 lb. and per ton.

REINFORCING-BAR LIST

Size of bars, in.	Lin. ft.	Number of bars			Bends	Hooks
		0–10 ft.	10–20 ft.	20–30 ft.		
⅜ round.	1,032	14	44	16	None	None
⅝ round	1,266	42	66	0	86	65
¾ round.	1,972	57	52	28	56	109
1 round.	2,846	96	74	38	72	110
½ square.	186	...	14	..	None	None
1 square.	192	..	12	..	None	None
⅜ round, ties.	714	102	..	..	408	None
⅜ round, stirrups.	976	324	..	..	648	648

All bars are deformed except the ⅜-in. round ties (for columns), which are plain.

Materials.—The weights and costs of the steel may be tabulated and summed up as in the following table.

Size of bars, in.	Lin. ft.	Wt., lb. per ft.	Wt., lb.	Unit costs					Total cost
				Base	Quantity	Size	Freight, del.	Total	
3/8 round	1,092	0.376	411	$2.60	$0.15	$0.40	$0.35	$3.50	$ 14.40
5/8 round	1,266	1.04	1,317	2.60	0.15	0.10	0.35	3.20	42.10
3/4 round	1,972	1.50	2,960	2.60	0.15	.....	0.35	3.10	91.80
1 round...........	2,846	2.67	7,600	2.60	0.15	.....	0.35	3.10	235.60
1/2 square..........	186	0.85	158	2.60	0.15	0.20	0.35	3.30	5.20
1 square	192	3.40	653	2.60	0.15	.....	0.35	3.10	20.25
3/8 round, ties......	714	0.376	268	2.60	0.15	0.40	0.35	3.50	9.40
3/8 round, stirrups..	976	0.376	367	2.60	0.15	0.40	0.35	3.50	12.85
Total for bars......	.....	.....	13,734	.....	.....	.....	.....	$3.14	$431.60
Allowance for spacers and wire at $0.30 per 100 lb. of bars....................									$ 41.20
Total for all steel delivered at job site....................................									$472.80

LABOR COST OF PLACING BARS

Size of bars, in.	Length 0–10 ft.				Length 10–20 ft.				Length 20–30 ft.				Total cost
	No. of bars	Labor-hr. per 100 bars	Cost per bar	Labor cost	No. of bars	Labor-hr. per 100 bars	Cost per bar	Labor cost	No. of bars	Labor-hr. per 100 bars	Cost per bar	Labor cost	
3/8 round..................	14	4.0	$0.034	$ 0.48	44	5.5	$0.047	$ 2.07	16	6.5	$0.055	$0.88	
5/8 round..................	42	5.0	0.0425	1.70	66	6.5	0.055	3.63	0				
3/4 round..................	57	5.5	0.047	2.68	52	7.0	0.059	3.07	28	8.0	0.068	1.90	
1 round....................	96	6.0	0.051	4.90	74	7.5	0.064	4.73	38	9.0	0.077	2.92	
1/2 square.................	0	...	....	......	14	6.5	0.055	0.77	0				
1 square...................	0	...	....	......	12	9.0	0.077	0.93	0				
3/8 round ties.............	102	...	....	......	0	...	......	......	0				
3/8 round stirrups..........	324	5.0	0.0425	13.80	0	...	......	......	0				
Total.....................	...	...	....	$23.65	..	...	......	$15.20	..	...	......	$5.70	$44.55

No labor costs are apportioned to the ⅜-in. round ties for columns, as the cost of securing these in place is included with the labor cost of placing the ½-in. square and 1-in. square column bars.

On a job of this size, many estimators, perhaps, would not go into as much detail in preparing the labor estimate. In this particular problem, the labor estimate is worked out in detail so that the use of the method will be understood.

Total labor-hours for placing = \$44.55 ÷ \$0.85 = 52.5 hr.

Total labor costs, bending and placing = \$26.05 + \$44.55 = \$70.60

Plant.—The plant required for this job would be 1 machine bender, about 2 benches, and several hand tools. Plant charge may be estimated at about \$0.0125 per 100 lb. of bars, or about \$1.60. To this must be added the costs of trucking bender and tool box to and from the job, say \$2 for each. Total plant = \$5.60.

Overhead.—This will be 31 per cent of the labor cost, and equals 31 per cent of \$70.60, or \$21.90.

Profit.—This will be 9 per cent of all of the other costs, or 9 per cent of the sum of \$472.80 + 70.60 + 5.60 + 21.90, and equals \$51.40.

Summary.—The total estimate, on the assumption that this job is a complete job by itself, including overhead and profit, will be summarized as follows:

Item	Unit Cost per 100 Lb.	Unit Cost per Ton	Total Cost
Materials	\$3.44	\$68.80	\$472.80
Labor	0.51	10.20	70.60
Plant	0.04	0.80	5.60
Overhead	0.16	3.20	21.90
Profit	0.37	7.50	51.40
Total	\$4.52	\$90.50	\$622.30

D. ESTIMATING SURFACE FINISH

30. Units of Measurement.—Surface finish of concrete surfaces is usually measured by the square foot, except for such work as finishing coves and molding when the lineal foot is used.

Some allowance should be made for going over the surfaces of concrete work after the removal of forms, patching up voids and stone pockets if any are present, removing fins, etc. On some jobs, this work is included with the labor required for stripping and cleaning of forms. However, on other jobs, the contractors consider the work of surface cleaning or finishing as a separate item and prepare their estimates accordingly.

All different types of surface finish should be measured and described separately. That is, the kinds of finish (troweling, rubbing, tooling, scrubbing, washing, sandblasting, terrazzo

granolithic, etc.) should be listed separately with enough explanation so that a reasonable estimate of the required materials, labor, and plant may be prepared.

31. Materials.—No materials are required for such types of finishing as simple troweling, washing, and rubbing, but materials are needed for a cement-mortar finish, and for terrazzo and granolithic finishes.

The quantities of cement and aggregate required for 100 sq. ft. of surfacing 1 in. thick will depend upon the mix. Table 5-16 gives the quantities required for various mixes. Quantities required for other thicknesses are readily computed from the values given. The aggregate may be all sand, part sand and part fine crushed stone, sand with stone (granite or marble) chips for surfacing, or all fine crushed stone.

TABLE 5-16.—APPROXIMATE QUANTITIES REQUIRED FOR 100 SQ. FT. OF SURFACE FINISH 1 IN. THICK

Material	Mix by volume				
	1–1	1–1½	1–2	1–2½	1–3
Cement, sack	6.0	4.8	4.0	3.5	3.0
Aggregate, cu. ft	6.0	7.2	8.0	8.5	9.0
	Mix by weight				
	1–1	1–1½	1–2	1–2½	1–3
Cement, lb	600	480	400	345	300
Aggregate, lb	600	720	800	860	900

An allowance of water for all purposes of about 75 to 150 gal. per 100 sq. ft. of surface is usually satisfactory.

The price of cement at the job will be found in the same manner as in Art. 17 of this chapter. The aggregates used are often special, such as washed and graded sand, graded stone chips, granite chips, or marble chips. These materials are often delivered in sacks weighing 100 to 200 lb. The price of aggregate at the job varies considerably and may range from about $0.10 to $0.50 per 100 lb.

32. Labor.—The approximate amounts of labor required for various types of surface finishing is given in Table 5-17.

TABLE 5-17.—APPROXIMATE LABOR-HOURS REQUIRED FOR FINISHING CONCRETE SURFACES

Kind of Work	Labor-hours
Troweling floor, walls, sidewalks, etc. (100 sq. ft.)	1– 4
Troweling plain base, cove, etc. (100 lin. ft.)	1– 4
Troweling fancy base, cove, etc. (100 lin. ft.)	3– 7
Carborundum rubbing of floor and wall surfaces (100 sq. ft.)	4–12
Carborundum rubbing of window sills, base, cove, etc. (100 lin. ft.)	4–14
Machine grinding (100 sq. ft.)	3–12
Ornamental tooling, various kinds (100 sq. ft.)	8–20
1-in. granolithic or terrazzo finish laid after concrete has hardened, including mixing and placing (100 sq. ft.)	7–15
1-in. granolithic or terrazzo finish laid integral with the concrete, including mixing and placing (100 sq. ft.)	5–12
Removing fins, patching pockets, etc. (100 sq. ft.)	1– 4
Scrubbing surface (100 sq. ft.)	2– 5
Washing surface with acid (100 sq. ft.)	2– 5
Sandblasting surface (100 sq. ft.)	3– 6
Cement or other surface work per coat, (100 sq. ft.)	2– 5

Skilled labor is required for surface finishing, though some unskilled labor may be used for helping in some instances. Prices of skilled labor for finishing may range from about \$1 to \$2 per hour.

Diagram 5-10 (page 579) may be used for estimating labor costs of surface finishing when the hourly wage and labor-hours required per 100 sq. ft. of surface are known or assumed.

33. Plant.—The plant required will vary from a few hand tools required for troweling to a combination of hand tools, small mixers and accompanying equipment, and machine grinders required for granolithic or terrazzo finish. Sandblasting requires a machine, hose, etc., and a supply of fine sand. Scaffolding of some sort must be provided when walls and ceilings are to be finished.

It is practically impossible to give any accurate plant costs in general because the requirements of the individual jobs vary so greatly. Plant costs may range from a few cents to several dollars per 100 sq. ft. of surface.

34. Overhead and Profit.—Overhead costs of surface finishing are usually based on labor costs and may range from about 20 to 50 per cent of the cost of labor.

The profit may range from about 5 to 20 per cent, depending upon circumstances.

35. Summary.—The total estimate for a surface-finishing job will include materials (if any required), labor, plant, overhead, and profit (if a separate job).

36. Illustrative Estimate on Surface Finishing.—Estimate the cost of 100 sq. ft. of terrazzo surface finish 2½ in. thick and placed in two courses. The first course is 1½ in. thick and is a mortar course composed of 1 part of portland cement to 3 parts by weight of sand. The second course is 1 in. thick and is composed of 1 part of portland cement to 2 parts by weight of marble chips. Prices of materials at the job are cement $0.70 per sack, sand $2.05 per ton, and marble chips $0.25 per 100 lb. Labor gang will consist of 1 foreman at $2 per hour, 2 finishers or grinders at $1.50 per hour, and 3 laborers at $1 per hour.

Estimate for first or base course. Mix is 1 to 3. Course is 1.5 in. thick (see Table 5-16).

Cement, pounds = 300 × 1.5 in. = 450 lb. = 4.8 sacks at $0.70	= $ 3.36
Sand, pounds = 900 × 1.5 = 1,350 lb. at $2.05 a ton	= 1.39
Water, estimated at	= 0.10
Materials	= $ 4.85
Labor, mixing, placing, striking off, say 2.50 hr., at average wage of $\left(\frac{\$2 + \$3 + \$3}{6}\right)$, or $1.33 per hr.	= $ 3.33
Plant, say about $1	= 1.00
Overhead, say 32 per cent of labor	= 1.07
Profit, say 10 per cent of other costs	= 1.03
Total for first course	= $11.28

Estimate for second or wearing course. Mix is 1 to 2. Course is 1 in. thick (see Table 5-16).

Cement, pounds = 400 = 4.25 sacks at $0.70	= $ 2.98
Marble chips, pounds = 800 at $0.25 per 100 lb.	= 2.00
Water, estimated at	= 0.10
Materials	= $ 5.08
Labor, mixing, placing, troweling, and grinding, say 7 hr. at an average wage of $1.33 per hr.	= $ 9.33
Plant, mixing and grinding, say about	1.25
Overhead, 32 per cent of labor	= 2.99
Profit, 10 per cent of other costs	= 1.87
Total for second or wearing course	= $20.52
Total for 100 sq. ft. both courses (or about $0.32 a square foot)	= $31.80

E. COMPLETE ESTIMATES

37. Complete Estimates.—A complete estimate of a structural concrete job will include costs of forms, concrete, reinforcement, and surface finishing (if required). Curing costs are usually included in the concrete estimate, though many estimators add a separate item for curing in cold weather.

On almost every large concrete job, there are a number of miscellaneous items which need consideration. Most estimators include these items or allow for them in the overhead charges apportioned to the different parts of the whole job. The percentages charged to overhead should be large enough to include all general overhead, cleaning up and miscellaneous items. Cleaning up may cost about $\frac{1}{10}$ of 1 per cent to $\frac{1}{2}$ of 1 per cent of the total costs. Miscellaneous and sundry expenses and contingencies may vary from about 2 to 5 per cent of the total cost. Such expenses should preferably be included in the allowance for overhead.

Some estimators use different percentages for overhead for the different parts of the work (forms, concrete, etc.) and include overhead and profit with the estimates for each kind of work. Other estimators use the same percentage for overhead for all parts of the work, and then include overhead and profit as separate items. The first method seems preferable.

38. Summary.—The complete estimate for the entire job may be divided and itemized and summarized as desired. On unit-price jobs, the cost per cubic yard of each class of concrete is tabulated.

When overhead and profit are apportioned among the different parts of the work, the estimate may be summarized as follows:

Item	Unit Cost per Cu. Yd.	Total Cost
Forms	$	$
Concrete		
Reinforcement		
Surface finishing		
Curing (if separate)		
Total estimate	$	$

If it is not desirable to apportion the overhead and profit, the summary may be as follows:

Item	Unit Cost per Cu. Yd.	Total Cost
Forms (materials, labor, and plant).	$	$
Concrete, (materials, labor, and plant)........................		
Reinforcement, (materials, labor, and plant)....................		
Surface finishing, (materials, labor, and plant)....................		
Curing (if separate) (materials, labor, and plant)....................		
Overhead......................		
Profit..........................		
Total estimate....................	$	$

Estimates for unit price jobs may be tabulated as follows for each class of concrete. Each item listed includes its proportion of overhead and profit.

Item	Class A Cost per Cu. Yd.	Class B Cost per Cu. Yd.	Etc.
Forms..........................	$	$	$
Concrete........................			
Reinforcement....................			
Curing (if separate)...............			
Surface finishing (if any)...........			
Total costs per cubic yard..........	$	$	$

When the overhead and profit are included as separate items, the summary may be as follows:

Item	Class A Cost per Cu. Yd.	Class B Cost per Cu. Yd.	Etc.
Forms..........................	$	$	$
Concrete........................			
Reinforcement....................			
Curing (if separate)...............			
Surface finishing (if any)...........			
Overhead........................			
Profit..........................			
Total costs per cubic yard..........	$	$	$

Total costs for any class of concrete would equal the unit cost multiplied by the yardage for that class. The total cost of the job would equal the sum of the total costs of the different classes of concrete.

F. ESTIMATING CONCRETE WALKS

39. Items Included.—Walks are usually built upon the ground, and floors may be built either on the ground or upon other constructions. The *subject of estimating of reinforced* concrete floors has been covered previously in this chapter. The work of building a sidewalk (or a floor upon the ground) may include the following items:

1. Excavation or fill.
2. Leveling and tamping the soil.
3. Placing, tamping, and leveling cinder base.
4. Placing screeds or forms where required.
5. Mixing and placing the concrete.
6. Finishing the concrete surface by troweling and tooling the surfaces and joints.
7. Curing the concrete.
8. Removing forms and cleaning up.

40. Units of Measurement.—Walks and floors are usually measured by the square foot with the thickness and mix stated. The thickness may vary from 3 to 6 in., 4 or 5 in. being common.

Practically all modern walks are constructed in one course with the cement measured in sacks or by weight, the aggregates by weight, and the water by U. S. gallons or pounds. However, some two-course walks are being built, and on some jobs the materials are measured by volume.

41. *Materials.*—*The subject of excavation and fill has been* covered in Chap. III. The reader is referred to that chapter for information on estimating excavation and fill.

Cinders.—The materials required for the cinder base will depend on whether or not this base is required and on the thickness specified. A thickness of 5 in. is recommended. Cinders are usually purchased by the cubic yard.

TABLE 5-18.—CINDERS REQUIRED FOR BASES FOR CONCRETE WALKS

Compacted thickness of base, inches	2	3	4	5	6
Cubic yards per 100 sq. ft. of walk, assuming cinders measured loose and compacting 25 per cent	0.83	1.24	1.65	2.06	2.47

The price of cinders delivered at the job will vary from about $1 a cubic yard and up, depending upon the first cost and the transportation costs.

Joint Filler.—The joint filler should be premolded strips of bitumen-filled fiber or mineral aggregate, 0.50 in. thick, as wide as the thickness of the concrete, and as long as the width of the walk.

Concrete Materials.—The quantities of materials required for 100 sq. ft. of walk will depend upon the thickness of the walk

TABLE 5-19.—MATERIALS REQUIRED FOR 100 SQ. FT. OF WALK
Proportions by weight

Mix and materials, 4-in. slump, medium	Thickness of walk, inches			
	3	4	5	6
	Quantities			
Mix 1–2.0–3.0, 6 gal. per sack:				
Cement, sacks	6.15	8.15	10.20	12.25
Sand, tons	0.60	0.77	0.95	1.15
Gravel, tons	0.88	1.15	1.45	1.75
Mix 1–2.5–4.0, 7.5 gal. per sack:				
Cement, sacks	4.95	6.55	8.20	9.85
Sand, tons	0.58	0.77	0.96	1.15
Gravel, tons	0.92	1.23	1.55	1.85

TABLE 5-20.—MATERIALS REQUIRED FOR 100 SQ. FT. OF WALK
Proportions by volume

Mix and materials, 4-in. slump, medium consistency	Thickness of walk, inches			
	3	4	5	6
	Quantities			
Mix 1–2.0–3.0, 6 gal. per sack:				
Cement, sacks	6.15	8.15	10.20	12.25
Sand, cubic yards	0.46	0.62	0.75	0.90
Gravel, cubic yards	0.68	0.90	1.15	1.35
Mix 1–2.5–4.0, 7.5 gal. per sack:				
Cement, sacks	4.95	6.55	8.20	9.85
Sand, cubic yards	0.46	0.62	0.75	0.90
Gravel, cubic yards	0.73	0.97	1.20	1.45

and the proportions of the mix. Whenever practical, the materials should be measured by weight. A thickness of 5 in. is recommended. For a one-course walk a 1–2–3 mix should be used. For good durability in unprotected places, a maximum of about 6 to 6.50 U. S. gal. of water per sack of cement is recommended. Tables 5-19 and 5-20 give the quantities of cement, sand and gravel required for different thicknesses and for different mixes. The aggregates are sand and 1-in. gravel.

42. Labor.—The labor required for constructing 100 sq. ft. of concrete sidewalk will depend upon the particular job, the skill of the gang, and the distances that the materials and concrete must be transported.

The cement and aggregate piles should be placed as close to the mixer as practicable, and the mixer should be located so that the distance that the concrete must be transported is a minimum. With a small mixer (about a one-half bag), a concrete crew of about 3 to 6 men is satisfactory. For a one-bag mixer, a crew of 5 to 10 men may be needed.

For good curing, a covering (canvas, burlap, sand, straw, etc.) should be placed over the fresh concrete as soon as the surface has hardened sufficiently, and this covering should be thoroughly wet at least twice a day on dry days for a week.

The approximate labor required for the construction of one-course concrete sidewalks is given in Table 5-21.

TABLE 5-21.—APPROXIMATE LABOR REQUIRED FOR CONCRETE SIDEWALKS

Item	Labor-hours per 100 Sq. Ft. of Walk
Leveling and tamping soil	1– 3
Placing, leveling, and tamping cinders	1– 3
Placing forms and screeds	1– 3
Mixing and placing concrete	2– 5
Finishing	1– 4
Curing, removing forms, cleaning up	1– 3
Total	7–20

Labor wages vary at different times and in different localities. Hourly wages are approximately as follows: foremen $1.50 to $3; finishers, mixer operators, carpenters $1 to $2.25; and ordinary labor $0.65 to $1.25.

43. Forms.—Either lumber or metal forms may be used. Lumber forms are usually 2 in. thick and of a width equal to

the depth of the walk. Metal forms should be strong. One stake is required for about every 3 to 5 ft. of form length. The lumber cost per lineal foot of forms will vary from about $0.05 to $0.13 for first cost. As the salvage value is high and the lumber may be used many times, the average cost (assuming salvage and reuse) will be about $0.02 to $0.05 per lineal foot. Metal forms will cost about the same or perhaps a little more. Some estimators consider the sidewalk forms as a part of the plant, and include the form costs with the plant costs.

44. Plant.—The plant and equipment required for the construction of concrete walks will include a small mixer, hose, water-measuring device, scale, barrows or carts, plank for runways, shovels, tampers, and hand tools for form builders and finishers.

The plant cost per cubic yard of concrete for a walk may range from about $0.35 to $3 per cubic yard of concrete, or from about $0.50 to $4 for 100 sq. ft. of walk 5 in. thick.

45. Overhead and Profit.—Overhead costs will probably range from about 20 to 50 per cent of the labor costs.

Profit may range from about 5 to 15 per cent, with about 10 per cent as a fair average value.

46. Summary.—The estimate for concrete walks may be summarized as follows:

Item	Unit Cost per Sq. Ft.	Total Cost
Materials	$	$
Labor		
Forms		
Plant		
Overhead		
Profit		
Total	$	$

47. Illustrative Estimate for Concrete Walks.—An estimate is required for a one-course concrete sidewalk 5 ft. wide and 620 ft. long. The walk is to be 5 in. thick and is to have a 4-in. cinder base. Concrete mix by weight with 1-in. aggregate is to be 1 to 2 to 3. Land surface conforms to grade so that there will be but little excavating and leveling. Prices of materials delivered at the job are cement $0.75 per sack net, sand $1.50 per ton, 1-in. gravel $1.70 per ton, and cinders $1.10 per cubic yard. Cost of water is nominal and may be taken at $0.20 per 100 sq. ft. of walk to allow for wetting down, concrete mixing, curing, and waste. Hourly wages of laborers and number of men in the crew are 1 foreman at $2, 1 mixer oper-

tor at $1.25, 1 finisher at $1.50, 1 handy man (rough carpenter) at $1.15, 4 laborers at $0.75 each. Plant costs are $1.05 per 100 sq. ft. of walk. Overhead is 25 per cent of labor cost. Profit is 10 per cent.

Concrete walk estimate. Take totals to nearest dollar.

Area = 620 × 5 = 3,100 sq. or 31 squares

			Cost per 100 Sq. Ft.	Total Cost
Materials:				
Cinders (see Table 5-18),	1.65 cu. yd.	at $1.10	= $ 1.82	$ 56
Cement (see Table 5-19),	10.20 sacks	at $0.75	= 7.65	237
Sand,	0.95 tons	at $1.50	= 1.42	44
Gravel,	1.45 tons	at $1.70	= 2.46	76
Water,			= 0.20	6
Asphalt-impregnated fiber for expansion joints, say			= 0.50	16
Total materials			= $14.05	$ 435
Labor:				
Average hourly rate is (2.00 + 1.25 + 1.50 + 1.15 + 4 × 0.75) ÷ 8 = $1.11				
Leveling and tamping soil, say 1 hr. at $0.75			= $ 0.75	$ 23
Spreading, tamping, and leveling cinders, say 2 hr. at $0.75			= 1.50	47
Forms, say 1 hr. at $1.15			= 1.15	36
Mixing and placing concrete, 4.5 hr. at $1.11			= 5.00	155
Finishing, 2 hr. at $1.50			= 3.00	93
Curing and cleaning up, say 2 hr. at $0.75			= 1.50	46
Total labor			= $12.90	$ 400

Forms. Say 2 × 20 = 40 ft. of 2-by-4's. Say 10 stakes.

Assume salvage value at 75 per cent and lumber at $90 per 1,000 ft. b.m.

$$\text{Cost of 2-by-4's} = \frac{40}{1{,}000} \times \frac{8}{12} \times \$90 \times (100\% - 75\%) = \$0.70.$$

	Cost per 100 Sq. Ft.	Total Cost
Cost of stakes, say $0.50 for 10. Total forms	= $ 1.20	$ 37
Plant	= 1.35	42
Overhead. 25 per cent of labor ($12.90)	= 3.23	100
Profit. 10 per cent of all other costs	= 3.27	102
Total estimate	= $36.00	$1,116

Unit cost per square foot is $0.36

G. ESTIMATING CONCRETE ROADS AND PAVEMENTS

48. Items Included in Estimate.—The items included in an estimate for a concrete highway would be materials, labor, plant, overhead, and profit. However, on most jobs it is often convenient to regroup these items according to the different divisions of the work. Such a regrouping may give:

1. Materials costs. Cost of cement, fine and coarse aggregates, water, reinforcement, and miscellaneous materials delivered to the contractor.

2. Materials yard. Costs of labor, equipment, and overhead, for handling, storing, and measuring materials at the materials yard (see Chap. II on Handling and Transporting Materials).

3. Transportation of materials. Costs of transporting materials to job (see Chap. II on Handling and Transporting Materials).

4. Construction of pavement. Costs of labor, equipment, and overhead required for constructing the concrete pavement. This will include

a. Excavation and fill. Usually the excavation and fill are constructed by a different contractor, and the roadway base is at grade. This item will rarely appear in concrete paving estimates (see Chap. III on Excavation).
b. Leveling subgrade. Occasionally some equipment and labor may be required for bringing the subgrade to the exact grade desired.
c. Providing water supply for mixer and for curing.
d. Forms. Placing and removing as work progresses.
e. Placing reinforcement, usually placed with concrete.
f. Mixing and placing concrete.
g. Finishing surface.
h. Curing.
i. Cleaning up (if considered as a separate item).

49. Units of Measurement.—The common unit of measurement for concrete roads and pavements is the square yard of pavement surface, with thickness, reinforcement, concrete mix, and other details stated. Sometimes other units, such as 100 sq. ft., 100 sq. yd., cubic yards per mile, cubic yards per station, foot-mile (1 ft. wide and 1 mile long), etc., have been used.

The materials that the contractor uses will be priced in other units, *e.g.*, such as

Cement, sacks, barrels, 100 lb., or tons.

Fine aggregate (sand), cubic yards or tons.

Coarse aggregate (gravel or crushed stone), cubic yards or tons.

Reinforcement, pounds or tons.

Water, gallons, 1,000 gal., etc.

50. Materials. *Concrete Materials.*—The materials required for concrete are cement, water, and fine and coarse aggregates.

The amounts of the different materials required per square yard of pavement will depend upon the proportion of the mix and the average thickness of the pavement section. Pavements vary from about 5 to 12 in. in average thickness, values of 6 to 9 in. being common. The amount of concrete required per square yard of pavement surface is as follows:

Thickness, Inches	Cu. Yd. of Concrete per Sq. Yd. of Surface
5	0.139
6	0.167
7	0.195
8	0.222
9	0.250
10	0.278
11	0.306
12	0.333

Many pavements have thickened edges, and the thickness consequently varies from one side to the other of the pavement. When estimating the quantity of concrete in cubic yards per square yard of pavement surface required for such pavements, the estimator first assumes a convenient length of pavement, then finds the cross-sectional area and multiplies this area by the assumed length to obtain the volume. Dividing this volume in cubic yards by the area of this portion of the pavement in square yards gives the average number of cubic yards of concrete required per square yard of pavement.

The consistency of the mix is very stiff. A slump of about 1 to 1.5 in. is common with machine finishing, and a slump of about 2 to 3 in. with hand finishing.

The proportions are practically always given by weight, and may vary from about 1–2–3.5 to 1–3–4.5, with water varying from 5 to 6 gal. (41.7 to 50 lb.) per 100 lb. of cement. The cement may vary from about 500 to 700 lb. per cubic yard of concrete. The mix is usually designed to give a 28-day modulus of rupture (cross-bending strength) of from 500 to 800 lb. per square inch, and a corresponding compressive strength of 3,500 to 6,000 lb. per square inch.

When the proportions are given, the estimator may compute the quantities of materials per cubic yard of concrete according to the methods explained in Section B of this chapter. Methods

After the materials yard costs per ton (or other suitable unit) have been found for each material, these costs may be reduced to unit costs per cubic yard of concrete or per square yard of pavement as desired.

Materials yard costs (plant, labor, and overhead) may range from a few cents up to a dollar or so per ton, depending upon the particular yard, and the proportional length of time it is operated. For a well-operated yard, the cost may vary from about $0.05 to $0.50 per ton.

If desired, an allowance for profit may be included when computing materials yard costs.

52. Materials Transportation.—The cost of transporting the materials from the materials yard to the job will include equipment, labor, and overhead costs (plus an allowance for profit if desired) for the trucks and drivers.

Perhaps the best way of estimating these transportation costs is to

1. Compute total hourly cost of truck and driver.
2. Compute time for one round trip in hours (load, travel loaded, unloaded, return, delays).
3. Compute cost per trip.
4. Compute cost per ton (or per cubic yard) for transporting materials by dividing cost per trip by tons carried per trip.
5. Reduce cost per ton to cost per square yard of pavement surface, noting that 1 cu. yd. of concrete weighs approximately 4,000 lb., or 2 tons.

The reader is referred to Chap. II on Handling and Transporting of Materials for methods of computing transportation costs.

53. Pavement Construction.—The items mentioned in Art. 48 (Items Included in Estimate) of this chapter will be discussed in order.

Excavation and Fill.—This work is usually done by another contractor, and will not be considered here.

Leveling Subgrade.—On almost every job, a little leveling of the subgrade will need to be done. An allowance of $0.35 to $1 per 100 sq. yd. of surface will be sufficient when the work of excavation and fill has been well done.

Providing Water Supply.—On some jobs, the water supply may be secured from a city or village. Then the plant needed

wages of the workmen. Approximate costs of placing reinforcement, per square yard of pavement, may range from about \$0.02 to \$0.08. On many jobs, the cost of placing reinforcement is included with the cost of mixing and placing the concrete.

Mixing and Placing Concrete.—The plant and labor costs of mixing and placing concrete in pavements will be comparatively low. Perhaps a cubic yard would be a better unit than the square yard for mixing and placing. Some estimators compute costs per cubic yard and then reduce them to costs per square yard. The transportation of the plant to and from the job must be included in the total costs. In general, labor costs vary inversely with plant costs. Approximate values, not including transportation of plant, are as follows:

Item	Per cubic yard	Per square yard
Labor-hours	1 – 2	0.25– 0.60
Labor cost	\$0.80–\$2.25	\$0.25–\$0.60
Plant costs	0.50– 2.25	0.15– 0.60
Overhead	0.35– 0.90	0.10– 0.25
Profit	0.20– 0.50	0.05– 0.15
Total costs, mixing and placing	\$2.20–\$5.10	\$0.60–\$1.40

canvas or burlap can be used several times, will be about as follows:

Covering materials	\$0.003–\$0.008
Water	0.004– 0.012
Labor	0.060– 0.210
Overhead	0.020– 0.080
Profit	0.010– 0.030
Total	\$0.100–\$0.340

Cleaning Up.—The cost of cleaning up the job will not be large, and will usually be less than 1 per cent of the sum of the other costs. Average costs may range from about \$0.003 to \$0.015 per square yard. Many estimators include the cost of cleaning up in their overhead costs.

54. Summary.—The cost items for a concrete-paving estimate may be tabulated and summed up in different ways. Some estimators consider overhead and profit as separate items, others include overhead and profit when estimating costs of different kinds of work, and others consider profit as a separate item and include overhead with the costs of various kinds of work. Many contractors prefer the last method. Overhead costs may range from 15 to 40 per cent of all other costs, or from 25 to 55 per cent of labor costs alone. Profit may range from 5 to 20 per cent of the sum of all other costs.

The tabulation may be as follows:

CHAPTER VI

MASONRY

Masonry includes structures or parts of structures that are built by a mason of such materials as stone, brick, block, and tile.

A. BRICK MASONRY

1. Brick Materials.—Brick may be classified as to manufacture (burning, casting), materials (clay, cement, sand lime), kind (ordinary or common, face brick), and size. For estimating purposes, the quantity, kind, cost, and size of brick and thickness of joint are important. Brick sizes range from 2 to 3 in. in thickness, 3¼ to 4½ in. in width, 7½ to 9 in. in length, and about 60 to 76 cu. in. in volume. The standard size is 2¼ by 3¾ by 8 in., with a volume of 67.5 cu. in., and a wall surface area (when laid as a stretcher) of 18 sq. in. The thickness of the

TABLE 6-1.—APPROXIMATE NUMBER OF BRICK REQUIRED FOR 1 CU. FT. OF WALL

Average volume of one brick, cu. in.	Thickness of mortar joint, inches			
	¼	5/16	⅜	½
	Number of brick			
60	23.7	22.4	21.1	18.6
62	23.3	21.9	20.4	18.2
64	22.4	21.3	19.9	17.8
66	21.9	20.8	19.6	17.4
67.5*	21.4	20.4	19.1	17.1
68	21.3	20.3	19.0	17.0
70	20.6	19.7	18.6	16.6
72	20.3	19.2	18.2	16.2
74	19.8	18.7	17.7	15.8
76	19.1	18.2	17.3	15.4

* Standard size.

joints may vary from $\frac{3}{16}$ to $\frac{3}{4}$ in., from $\frac{1}{4}$ to $\frac{1}{2}$ in. being common.

Many estimators base their estimates for the number of brick on the number of square feet of wall surface, with walls 1, 2, 3, or 4 brick thick as the case may be. Other estimators base their estimates on the number of cubic feet of wall.

Table 6-1 gives the approximate number of brick required per cubic foot of wall for varying sizes of brick and thicknesses of mortar joints.

A simple method for finding the number of brick required for 1 sq. ft. of wall of a thickness equal to the width of one brick is to lay out on a drawing board to scale a certain number of square feet of wall surface. Then the brick required for this area are counted and this number is divided by the square feet of wall surface to get the brick per square foot. This method is sufficiently correct for practical purposes.

Table 6-2 gives the number of brick required per square foot of wall surface for brick of different sizes and for varying thicknesses of joints, and for a wall one brick thick.

TABLE 6-2.—APPROXIMATE NUMBER OF BRICK REQUIRED PER SQUARE FOOT OF WALL SURFACE

Wall area of brick, sq. in.	Thickness of joint, inches					
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
	Number of brick					
16	7.75	7.50	7.25	6.80	6.35	6.00
17	7.35	7.10	6.90	6.45	6.05	5.75
18*	7.00	6.75	6.55	6.15	5.80	5.50
19	6.65	6.45	6.25	5.90	5.55	5.30
20	6.35	6.15	6.00	5.65	5.35	5.10
21	6.10	5.90	5.75	5.40	5.15	4.90
22	5.85	5.65	5.50	5.20	4.95	4.70
23	5.60	5.45	5.30	5.00	4.75	4.55

* Standard size.

The number of brick for a two-brick wall will be twice the values given in the table; for a three-brick wall, three times the values; and for a four-brick wall, four times the values.

Diagram 6-1 (page 580) shows the relations between wall area of brick, thicknesses of joints, and the number of brick required per 100 sq. ft. of wall surface.

Different procedures are followed when openings are considered. All large openings should be allowed for. Small openings (say about 2 sq. ft. or less) may be neglected unless there are many of them. Some estimators allow for all openings regardless of size, and other estimators allow for the larger openings only.

Some allowance must be made for breakage and waste. This allowance may vary from 2 to 5 per cent for common brick and from 1 to 3 per cent for face brick and special brick of various kinds.

The number of brick required for walls constructed of face brick backed with common brick may be estimated by making two take-offs, one for the face brick and the other for the common brick. Allowance should be made for headers when face brick are so used. For a check, the entire wall may be considered as being made of one kind of brick, and the total number of brick estimated. Thus, total number should equal the sum of the face and the common brick.

When estimating walls of brick veneer, usually consisting of a single thickness of stretcher courses, it is customary to include the metal ties for bonding the brick to the wall. The number of brick and ties per square foot of wall and for common, English, Flemish, or other bonds may be found by the method of sketching previously mentioned.

Brick are usually sold by the thousand; hence, the estimate in the take-off should tabulate the number of each kind of brick in thousands. The price per 1000 brick varies in different localities and for different kinds of brick. Prices may range from about $15 to $30 per 1000 for common brick up to $50 or more per 1000 for the better and more costly kinds of face brick. The price of brick may be quoted as f.o.b. manufacturers' or dealers' yard, f.o.b. nearest railway siding, or delivered at the job. If the price is not quoted as delivered at the job, the added expense of loading, transporting, and piling must be considered. See Chap. II on Handling and Transporting of Materials for ways of estimating handling and transportation costs per brick.

2. Mortar Materials.—The materials required for mortar per 1000 brick will depend upon the size of the brick, the thickness of the joints, and the proportions of the mix. Most mortar mixes include cement, lime, sand, and water. Sometimes *another ingredient*, such as coloring matter, is added. The cement improves the strength, and the lime improves the workability. Enough water is used to give a workable mix. The sand should be clean and hard and be fairly fine and uniform in grading. Cement is usually purchased by the sack or barrel, hydrated lime by the ton in 40- or 50-lb. sacks, and sand by the cubic yard or ton. Cement weighs 94 lb. per cubic foot, hydrated lime about 40 lb. per cubic foot, and sand 2,200 to 2,600 lb. per cubic yard.

The amount of mortar required for 1000 brick of standard size laid in a three-brick wall (12 in.) is approximately as follows:

TABLE 6-3.—MORTAR FOR 1000 STANDARD BRICK IN A THREE-BRICK WALL

Thickness of joint, in.	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4
Cu. yd. of mortar...	0.32	0.38	0.44	0.50	0.56	0.62	0.68	0.74	0.80
Cu. ft. of mortar...	8.65	10.25	11.90	13.50	15.10	16.75	18.35	20.00	21.60

These quantities are approximately correct, but will vary in practice because of variations in brick dimensions, thicknesses of joints, voids in sand, and completeness of filling of joints.

A thick wall usually requires a little more mortar per 1,000 brick than a thin wall. Considering the mortar required for a 12-in. (three-brick) wall as 100 per cent, the variation is about as follows:

Thickness of wall, in.	8	12	16	20	24
Percentage	95	100	103	106	108

The proportions of the mix are usually given by volume, though weight may be used. In stating the proportions, the *proportion of cement is usually given first, lime next, and then* sand.

Table 6-4 gives the quantities of cement, lime, and sand required for a cubic yard of mortar. Proportions are given by volume and by weight. When computing the tabular values,

TABLE 6-4.—MATERIALS REQUIRED FOR 1 CU. YD. OF MORTAR FOR BRICK MASONRY

Mix by volume, cement–lime–sand	Cement, sacks	Lime, lb.	Sand, cu. yd.	Mix by weight, cement–lime–sand	Cement, lb.	Lime, lb.	Sand, lb.
1–0.05–2	13.00	26	0.96	1–0.05–2	1,200	60	2,400
1–0.05–3	9.00	18	1.00	1–0.05–3	835	42	2,500
1–0.05–4	6.75	14	1.00	1–0.05–4	625	31	2,500
1–0.10–2	13.00	52	0.96	1–0.10–2	1,200	120	2,400
1–0.10–3	9.00	36	1.00	1–0.10–3	835	84	2,500
1–0.10–4	6.75	27	1.00	1–0.10–4	625	63	2,500
1–0.25–2	12.70	127	0.94	1–0.25–2	1,150	290	2,300
1–0.25–3	9.00	90	1.00	1–0.25–3	835	210	2,450
1–0.25–4	6.75	67	1.00	1–0.25–4	625	155	2,500
1–0.50–2	12.40	250	0.92	1–0.50–2	1,150	575	2,300
1–0.50–3	8.80	175	0.98	1–0.50–3	800	400	2,400
1–0.50–4	6.75	135	1.00	1–0.50–4	615	305	2,450
1–0.50–5	5.40	110	1.00	1–0.50–5	500	250	2,500
1–1–3	8.60	345	0.95	1–1–3	770	770	2,300
1–1–4	6.60	270	0.98	1–1–4	600	600	2,400
1–1–5	5.40	210	1.00	1–1–5	490	490	2,450
1–1–6	4.50	180	1.00	1–1–6	420	420	2,500
1–1.5–3	8.10	485	0.90	1–1.5–4	575	865	2,300
1–1.5–4	6.35	380	0.94	1–1.5–5	480	720	2,400
1–1.5–5	5.30	320	0.98	1–1.5–6	420	630	2,500
1–1.5–6	4.50	270	1.00	1–1.5–7	355	535	2,500
1–1.5–7	3.85	230	1.00	1–1.5–8	315	470	2,500
1–1.5–8	3.40	205	1.00	1–1.5–9	280	420	2,500
1–2–4	6.10	490	0.90	1–2–5	460	920	2,300
1–2–5	5.10	410	0.94	1–2–6	400	800	2,400
1–2–6	4.40	350	0.98	1–2–7	360	720	2,500
1–2–7	3.85	310	1.00	1–2–8	315	625	2,500
1–2–8	3.40	270	1.00	1–2–9	280	560	2,500
1–2–9	3.00	240	1.00				

one sack of cement was taken as 1 cu. ft., 40 lb. of hydrated lime as 1 cu. ft., and 2,500 lb. of sand as 1 cu. yd. Approximately 1 cu. yd. or 2,500 lb. (1.25 tons) of sand will be required for 1 cu. yd. of mortar.

Diagrams 6-2, 6-3, and 6-4 (pages 581, 582, and 583) may be used for finding the costs of the cement, lime, and sand per cubic yard of mortar when the proportions of the mix and the unit costs of the materials are known.

Diagram 6-5 (page 584) may be used for finding the cost of the mortar for 1,000 brick when the quantity required and the cost per cubic yard are known. The cost of 1 cu. yd. of mortar is equal to the sum of the costs of the cement, lime, sand, and water. Approximately 1 cu. yd. (2,500 lb.) of sand is required for 1 cu. yd. of mortar.

The amount of water used per 1000 brick may vary from about 30 to 100 gal., depending on the amounts used for mortar, washing, and waste. The cost of the water may vary considerably in different places. From \$0.02 to \$0.05 per 1000 brick may be assumed as the cost of water.

For cleaning brick walls, a mixture of 1 part muriatic acid to about 20 parts water is commonly used. One gallon of muriatic acid weighs about 10 lb. and (when mixed with water) will clean about 1,000 sq. ft. of brick surface. The cost of 1 gal. of muriatic acid is usually less than \$1; hence, the cost for cleaning purposes will usually be less than \$1 per 1000 sq. ft. of brick surface.

The costs of the materials will vary considerably at different times and in different localities. For example, the price of cement may vary from about \$0.55 to \$0.75 per sack for carload lots f.o.b. mills plus transportation to job, or the price may range from \$0.65 to \$1 per sack delivered at the job. The price of hydrated lime may vary from \$15 to \$30 per ton f.o.b. railway siding plus transportation to the job. Sand may cost \$1 to \$2.75 a ton, or \$1.25 to \$3.50 per cubic yard f.o.b. railway siding, at dealer's yard, or delivered at the job.

3. Labor.—There are two classes of labor used in brick masonry, the masons (bricklayers) and the helpers. The masons lay the brick and point the joints. The helpers mix the mortar, keep the masons supplied with brick and mortar, and erect, move, and dismantle scaffolding as required. Cleaning of the brick wall may be done by masons, helpers, or both. In cold

weather, the work of heating and protection is usually done by the helpers.

Usually the number of the helpers will be equal to the number of bricklayers. The proportion of helpers to masons will depend upon the work, and may vary from one helper to two bricklayers to three helpers to two bricklayers, according to the difficulty of keeping the bricklayers busy.

When brick and mortar must be transported vertically for one or more stories, a hoist should be used in preference to carrying the brick and mortar in hods up and down ladders. A hand hoist is suitable on small jobs. On large jobs, a power hoist will prove economical. See Art. 4 on Equipment for costs of hoists.

TABLE 6-5.—APPROXIMATE RATES OF LAYING BRICK

Description	Brick per hour	Hours per 1000 brick
Common brick		
Joints struck on one side of wall:		
2-brick wall	70–125	8.0–14.3
3-brick wall	80–150	6.7–12.5
4-brick wall	90–175	5.7–11.1
5-brick wall	100–200	5.0–10.0
6-brick wall	110–225	4.5– 9.1
Common brick		
Joints struck on two sides of wall:		
2-brick wall	60–110	9.1–16.7
3-brick wall	70–135	7.4–14.3
4-brick wall	80–160	6.3–12.5
5-brick wall	90–180	5.5–11.1
6-brick wall	100–200	5.0–10.0
Face brick		
Joints struck on two sides of wall:		
Common bond	50–100	10.0–20.0
Special bonds	40– 80	12.5–25.0
Boiler settings	40– 80	12.5–25.0
Fireplaces	30– 50	20.0–33.3

The wages of a bricklayer may range from $1.25 to $2 per hour, depending upon the locality and other considerations. Corresponding wages of helpers may range from $0.65 to $1.50 per hour.

The number of brick laid per hour by a bricklayer will depend upon several things, such as kind of brick (face or common), kind of joints, kind of mortar, thickness of wall, number of openings, pilasters, corners, paneling, working conditions, union and other regulations, and skill and inclination of the workers. Table 6-5 gives approximate rates of work for laying brick.

The labor required for pointing will depend primarily upon the type of joint. Ordinary joints such as struck, plain cut, rodded, or V joints may be made as the brick are laid, and require no extra time. Special joints, where some of the mortar is raked out and replaced by special mortar that is struck, rodded, beaded, etc., require extra labor which must be allowed for. The cost of special pointing is usually based on the square foot of brick surface. One mason should be able to point 10 to 40 sq. ft. of surface per hour, depending upon the kind of joint.

The amount of work done per hour by the helper will vary greatly. The following are approximate rates of work. A good helper can in 1 hr. do one of the following items of work:

Mix 0.40 to 0.60 cu. yd. of mortar.

Load and wheel (with a barrow) 700 to 1,200 brick a distance of 40 to 50 ft. and dump them on a scaffold.

Carry 400 to 600 brick in a hod up to a height of 10 ft.

Cull 200 to 400 brick.

Load and wheel (with a barrow) 0.7 to 1.2 cu. yd. of mortar a distance of 40 to 50 ft.

Handle from truck and pile 300 to 600 brick.

Two good helpers can, in 1 hour, do one of the following:

Handle 12 to 20 lin. ft. of pole staging.

Take down and move horse scaffolds for about 10 to 12 bricklayers working on thick walls, say 2 ft. or more thick.

Take down and move horse scaffolds for about 5 to 8 bricklayers working on 8- or 12-in. walls.

There are several ways of estimating the amount of work to be done. One method is to use the entire wall surface, with no allowance for openings, and the thicknesses of the wall (two or three brick, etc.). The reason for this is that the extra labor required for laying brick around the openings is about balanced by the labor saved by the openings. Another method is not to allow for any openings less than about 4 or 6 sq. ft. and to allow half for the larger openings. A third, and perhaps better, way

is to base the labor on the actual number of brick laid, giving consideration to the extra work required as around openings, in panels, for pilasters, for panels, and for corners.

When preparing labor estimates of brickwork, the number of bricklayers and helpers in the gang should be determined, the total hourly wages found, and the average cost per bricklayer (including proportionate cost of helper) computed. The rate of work should then be carefully assumed, and the labor cost per 1000 brick figured. The total labor cost will equal the cost per 1000 brick multiplied by the number of brick in thousands. The cost should also include the expense of pointing and cleaning when this work is to be done.

Diagram 6-6 (page 585) may be used for determining the labor cost per 1000 brick when the hourly wage of the bricklayer and helper is known and the brick laid per hour per bricklayer may be reasonably assumed.

4. Equipment.—The equipment required on a bricklaying job may include the following:

Bricklayer's hand tools	Wheelbarrows
Mortar boxes	Mortar tubs or boards
Mortar mixer	Brick and mortar hods
Sand screen	Scaffolding
Shovels	Hand hoist
Hoes	Power hoist
Hose	Elevator tower and requisite hoisting equipment
Water barrel	

The cost of this equipment may include such items as first cost, interest, depreciation, rentals, repairs, transportation to and from job, erection and dismantling, operation (fuel, oil, grease, etc.), and wages of operators.

For the various hand tools used, an allowance of $0.25 to $1 per 1000 brick is usually adequate.

A small mortar mixer with a gasoline engine will cost $0.20 to $0.50 per hour of operation plus wages of operation plus transportation and repairs.

The cost of a hand hoist will be a few cents per hour plus transportation to and from the job.

The cost of a power hoist will depend upon size and capacity of the hoist and amount and kind of other equipment such as eleva-

tor tower. Operating costs with one operator may range from \$2 to \$6 per hour plus transportation, plus erection and dismantling, plus repairs. A power hoist may be capable of elevating 2,000 to 10,000 brick a vertical distance up to 30 ft. in 1 hr.

The cost of scaffolding will vary considerably with the amount required and the type used. Ordinary horse scaffolds will cost but a few cents per 1000 brick (assuming moving to be done by helpers) plus transportation. Special scaffold machines (such as may be used on a steel building three or more stories high) may be rented for \$4 to \$15 per week per machine, including transportation, erection, and dismantling. Pole or post scaffolds, such as are ordinarily used on the outside of a building, will cost \$0.50 to \$1 per 1000 brick, on the assumption that the erection and dismantling will be done by the helpers and that most of the lumber can be salvaged. If carpenters have to be employed for the erection and dismantling of these scaffolds, the cost will be considerably higher, and may vary from \$0.75 to \$3 or \$4 per 1000 brick.

The total cost of equipment will be the sum of the costs of all the types and kinds of equipment used on the job.

5. Brick Masonry Estimates.—The cost estimate for brick masonry may be summarized as follows for each kind of brick and type of work.

Item	Cost per 1000 Brick	Total Cost
Materials (brick and mortar)......	\$	\$
Labor........................		
Equipment....................		
Overhead.....................		
Profit.......................		
Total........................	\$	\$

The costs of materials, labor, and equipment or plant may be found as directed in the preceding articles.

Overhead may be based on the sum of the costs of materials, labor, and equipment or on the cost of labor alone. The percentage allowed for overhead may range from about 10 to 25 per cent when based on the sum of the costs of materials, labor, and equipment, and from about 20 to 50 per cent when based on labor costs alone.

use an output of 90 brick per hour or 11 hr. per 1000 brick for this estimate. Hours required for the job = 11 × 61.74, or 679, hr. for one bricklayer, or 679 ÷ 3 or about 227 hr. for the gang for laying the brick.
No extra time will be required for pointing as the joints may be struck when the brick are laid.
No extra time need be allowed for wire brushing the walls if the helpers will go over the walls near the close of each day's work.

Labor cost = \$7.65 × 227 = \$1,736.55

Equipment:

Cost of mortar boxes, hoes, barrows, hods, etc., will be \$0.40 to \$0.80 per 1000 brick for a job of this kind, or \$0.60 × 61.74	= \$	37.05
Cost of mortar mixer = \$0.25 × 227 + \$4	=	60.75
Cost of horse scaffolds, including transportation, may be about \$0.50 per 1000 brick, or \$0.50 × 61.74	=	30.90
Total cost of equipment	= \$	128.70

Overhead:
No overhead cost is given in the problem. Perhaps a fair percentage would be about 15 based on other costs or 35 based on labor costs alone. Using 35 of labor costs, the overhead cost = \$1,736.55 × 0.35 = \$607.80

Profit:
Profit will be assumed as 10 per cent of all other costs.
(1435.45 + 1,736.55 + 128.70 + 607.80) × 0.10 = \$390.85.

Summary:
The cost per 1000 brick is based on 61.74 thousand.

Item	Cost per 1000 Brick	Total Cost
Materials	\$23.25	\$1,435
Labor	28.15	1,737
Equipment	2.10	129
Overhead	9.85	608
Profit	6.35	391
Total	\$69.70	\$4,300

B. STONE MASONRY

7. Stone-masonry Classification.—Stone masonry consists of walls or other structures built of stone usually bound together by mortar. A classification of stone masonry is as follows:

1. Dry masonry in which no mortar is used. Slope walls, stone paving, and riprap are examples.
2. Wet or mortar masonry in which mortar is used.
   a. Rubble masonry which is composed of rough unsquared stone as it comes from the field or quarry.

b. Squared-stone masonry in which the stones are roughly squared and dressed on beds and joints. The thickness of the mortar required in the joints is more than ½ in. The stones may be laid in courses (range), broken courses (broken range), or no courses (random).

c. Cut stone or ashlar masonry in which the stone is cut and the thickness of the mortar in the joints is less than ½ in. The ashlar masonry may or may not be laid in courses.

Stone veneer consists of a thin layer of cut stone on the face of the wall, and tied or bonded to the backing masonry of brick or stone.

Stone trim consists of cut stone used for such purposes such as water tables, lintels, copings, and ornamental courses in buildings.

Table 6-6 gives some of the different kinds of stone used for masonry and the approximate weights per cubic foot.

TABLE 6-6

Stone	Weight, Lb. per Cu. Ft.
Granite	165–170
Sandstone	145–150
Marble	165–170
Limestone	140–160
Slate	170–175
Trap	180–185

8. Estimating Stone.—The units of measurement may be the cubic yard or cubic foot for rubble and squared-stone masonry, the cubic foot for cut-stone work, and the cubic foot or the lineal foot for stone trim. Stone veneer may be estimated by the cubic foot or by the square foot of surface with the thickness being given.

When measuring walls, the length is usually measured along the outside and then multiplied by the height and thickness. Allowance should be made for all openings when figuring quantities of materials, though no deductions are usually made for corners.

The volume of the stone required will be less than the volume of the wall because of the space occupied by the mortar. Mortar may form 15 to 40 per cent of the volume in rubble masonry, 10 to 25 per cent in squared-stone masonry, and 4 to 10 per cent in ashlar masonry. The waste of stone may vary from prac-

tically nothing, when cut stone is purchased already dressed, up to as much as 20 per cent when the cutting and dressing are done at the job.

The cost of the stone delivered at the job may include cost of stone at quarry (rough or dressed), freight from quarry, and transportation from railway siding to job.

The cost of the stone at the quarry may vary about as follows:

Kind of Stone	Cost per Cubic Foot
Rough stone	$0.25–$0.40
Special stone (such as special limestones)	0.60– 2.00
Special stone, squared in two sides	0.90– 2.50
Special stone, squared on four sides	1.20– 3.50
Special stone, cut, finished, and crated	3.00– 6.00
Special stone, carved and crated	5.00– 7.00

These prices are approximate only. Consequently, the estimator should, whenever possible, secure prices from the quarry or the dealer for the stone f.o.b. quarry, f.o.b. siding nearest the job, or delivered at the job.

Anchors and dowels are required on many jobs. Roughly one anchor or dowel, costing $0.05 to $0.15, will be required for each cubic foot of masonry.

9. Mortar Materials.—The materials required for mortar for stone masonry are cement, lime, and sand plus such special ingredients as are required. The proportions for the mortar may vary from 1–2 to 1–4 for portland cement and sand plus small amounts of lime; to 1–1–3, 1–1–4, 1–1–5, 1–1–6, etc., for cement, lime, and sand; and to 1–2–4, 1–2–5, 1–2–6, 1–2–8, 1–2–9 when a larger proportion of lime is desired. Proportions are usually by volume, though proportions by weight are coming into use.

The amount of mortar required will depend upon the size of the individual stones and the thickness of the joints. Only approximate amounts may be given.

The cubic yards of mortar required for 1 cu. yd. of stone masonry may range about as follows:

Table 6-7

Kind of Masonry	Cubic Yards of Mortar
Rubble masonry	0.15–0.40 (average 0.25)
Squared-stone masonry	0.10–0.25 (average 0.15)
Cut-stone or ashlar masonry	0.04–0.10 (average 0.07)

Table 6-8 gives the quantities of materials required per cubic yard of mortar of varying proportions. When computing these values, one sack of cement was taken as 1 cu. ft., 40 lb. hydrated lime as 1 cu. ft., and 2,500 lb. of sand as 1 cu. yd.

TABLE 6-8.—MATERIALS REQUIRED FOR 1 CU. YD. OF MORTAR FOR STONE MASONRY

Mix by volume cement–lime–sand	Cement, sacks	Lime, lb.	Sand, cu. yd.
1–0.10–2	13.00	52	0.96
1–0.10–3	9.00	36	1.00
1–0.10–4	6.75	27	1.00
1–0.25–2	12.70	127	0.94
1–0.25–3	9.00	90	1.00
1–0.25–4	6.75	67	1.00
1–0.50–2	12.40	250	0.92
1–0.50–3	8.80	175	0.98
1–0.50–4	6.75	135	1.00
1–0.50–5	5.40	110	1.00
1–1–3	8.60	345	0.95
1–1–4	6.70	270	0.98
1–1–5	5.40	210	1.00
1–1–6	4.50	180	1.00
1–1.5–3	8.10	485	0.90
1–1.5–4	6.35	380	0.94
1–1.5–5	5.30	320	0.98
1–1.5–6	4.50	270	1.00
1–1.5–7	3.85	230	1.00
1–1.5–8	3.40	205	1.00
1–2–4	6.10	490	0.90
1–2–5	5.10	410	0.94
1–2–6	4.40	350	0.98
1–2–7	3.85	310	1.00
1–2–8	3.40	270	1.00
1–2–9	3.00	240	1.00

Mix by weight cement–lime–sand	Cement, lb.	Lime, lb.	Sand, lb.
1–0.05–2	1,200	60	2,400
1–0.05–3	835	42	2,500
1–0.05–4	625	31	2,500
1–0.10–2	1,200	120	2,400
1–0.10–3	835	84	2,500
1–0.10–4	625	63	2,500
1–0.25–2	1,150	290	2,300
1–0.25–3	835	210	2,450
1–0.25–4	625	155	2,500
1–0.50–3	800	400	2,400
1–0.50–4	615	305	2,450
1–0.50–5	500	250	2,500
1–0.50–6	420	210	2,500
1–1–4	600	600	2,400
1–1–5	490	490	2,450
1–1–6	420	420	2,500
1–1–7	355	355	2,500
1–1–8	315	315	2,500
1–1.5–5	480	720	2,400
1–1.5–6	420	630	2,500
1–1.5–7	355	535	2,500
1–1.5–8	315	470	2,500
1–1.5–9	280	420	2,500

The cost of mortar materials delivered at the job will range about as follows: cement $0.65 to $1 a sack, hydrated lime $18 to

$35 per ton, and sand $1 to $2.75 per ton or $1.25 to $3.50 per cubic yard.

The water required may vary from about 100 to 200 gal. per cubic yard of mortar, depending on the amounts wasted and used for washing, etc. An allowance of $0.06 to $0.15 per cubic yard of mortar is usually satisfactory.

Diagrams 6-2, 6-3, 6-4, and 6-7 (page 586) may be used for estimating costs of materials for mortar for stone masonry.

10. Labor.—The labor required for stone masonry may vary considerably according to the kind of masonry, amount of cutting and dressing required, working conditions, and skill and inclination of the men. Approximate labor outputs are given in Table 6-9.

If the individual stones are not too heavy or if the distance to be carried is not too great, all the work may be done by hand labor. Hand or power hoists or derricks should be provided for handling the heavier stones and for raising the stones vertically if the lift is about 10 ft. or more.

The problem in stonework is to keep the mason supplied with stone and mortar so that he will be busy all the working hours. All manual labor should be performed by the less skilled men whenever practical. A mortar mixer may be used on larger jobs.

In many localities, the masonwork is let by the job at so much per cubic yard or per cubic foot. When computing the number of cubic feet of masonry as a basis for labor, most localities do not allow any deductions for openings, and the minimum thickness of wall may be taken as 18 in. even if the actual thickness is less. In other localities, part or all openings above a certain size are deducted. The estimator must be informed in regard to local customs before preparing labor estimates.

On many jobs, a certain amount of cutting, trimming, fitting, and hammering may be required even though the cut stones are supposed to be cut to the correct dimensions before being shipped to the job. The amount of labor to allow for such extra work is difficult to estimate in advance. Some estimators allow for this extra work when estimating the hourly output of the crew. Other estimators figure this extra work as an extra item of cost. One cutter or fitter may be needed full time on a medium-sized job, and more on large jobs, to care for this extra work. The cost of such work must not be neglected.

TABLE 6-9.—LABOR REQUIRED FOR STONE MASONRY

Kind of work	Crew, approximate	Output of crew	
		Per hour	Per unit of work
Preparing stone:	1 cutter		
Rough squaring		2 –10 cu. ft.	2.5 –13 hr. per cu. yd.
Smoothing beds and builds		1.5– 4 sq. ft.	0.25– 0.7 hr. per sq. ft.
Hammering		0.8– 2 sq. ft.	0.5 – 1.2 hr. per sq. ft.
Find hammering		0.3–0.7 sq. ft.	1.5 – 3 hr. per sq. ft.
Laying stone by hand:	1 mason, 1 to 3 helpers as needed		
Rubble		4–11 cu. ft.	2.5–7 hr. per cu. yd.
Rough squared		4–11 cu. ft.	2.5–7 hr. per cu. yd.
Cut stone or ashlar		3– 8 cu. ft.	3.5–9 hr. per cu. yd.
Cut-stone trim		3– 7 cu. ft.	4 –9 hr. per cu. yd.
Cut-stone veneer (about 4 or 6 in. thick)		5–10 sq. ft.	1 –2 hr. per sq. yd.
Laying stone with aid of hand hoist or derrick:	1 mason, 1 to 3 helpers as needed		
All kinds of masonry		6–15 cu. ft.	2 –4.5 hr. per cu. yd.
Cut-stone trim		4–10 cu. ft.	3 –7 hr. per cu. yd.
Cut-stone veneer		7–15 sq. ft.	0.6–1.3 hr. per sq. yd.
Laying stone with aid of hand hoist or derrick:	1 mason, 3 to 6 helpers as needed		
Masonry		7–18 cu. ft.	1.3–4 hr. per cu. yd.
Cut-stone trim		5–12 cu. ft.	2.3–5.5 hr. per cu. yd.
Cut-stone veneer		9–18 sq. ft.	0.5–1 hr. per sq. yd.
Laying stone with aid of power hoist or derrick:	1 mason, 1 operator, 3 to 6 helpers as needed		
Masonry		13–27 cu. ft.	1 –2 hr. per cu. yd.
Cut-stone trim		9–21 cu. ft.	1.3–3 hr. per cu. yd.
Cut-stone veneer		15–30 sq. ft.	0.3–0.6 hr. per sq. yd.
Laying stone with aid of power hoist or derrick:	1 operator, 2 or 3 masons, 8 to 12 helpers as needed		
Heavy foundation		27–54 cu. ft.	0.5 –1 hr. per cu. yd.
Medium masonry		18–40 cu. ft.	0.7 –1.5 hr. per cu. yd.
Cut-stone trim		12–30 cu. ft.	0.9 –2.2 hr. per cu. yd.
Cut-stone veneer		25–60 sq. ft.	0.15–0.35 hr. per sq. yd.
Pointing:	1 mason, ½ to 1 helper as needed		
Simple		20–50 sq. ft.	0.2 –0.5 hr. per sq. yd.
Special		10–30 sq. ft.	0.3 –0.9 hr. per sq. yd.
Cleaning	1 man	20–70 sq. ft.	0.15–0.5 hr. per sq. yd.

Labor wages of stonemasons (layers and cutters) may vary from about \$1.25 to \$2 per hour, power-hoist operator from \$1.25 to \$2 per hour, helpers from \$0.65 to \$1.50 per hour, and ordinary labor from \$0.60 to \$1.25 per hour.

Diagrams 6-8, 6-9, and 6-10 (pages 587, 588, and 589) may be used for estimating labor costs of laying stonemasonry when the hourly wage of the mason and helpers or the crew is known and the output may be reasonably assumed.

11. Equipment.—The equipment required for stonemasonry work may include the following:

Mason's hand tools, trowels, hammers, sledges, bars, etc.

Mortar box	Water barrel
Screens	Hand hoist or derrick
Mortar mixer	Power hoist or derrick
Mortar hods	Mortar tubs or boards
Mixing tools	Barrows
Hose	Scaffolding

For the various hand tools, an allowance of \$0.05 to \$0.40 per hour per mason will be sufficient depending upon the size of the crew and number of tools. Transportation costs to and from the job are extra.

Small power tools (such as hammers) may cost a few cents up to about \$0.30 per hour.

A small mortar mixer, engine or motor driven, may cost \$0.20 to \$0.50 per hour of operation plus operator plus transportation.

The cost of a hand hoist or derrick may vary from about \$0.05 to \$0.20 per hour depending upon size, plus transportation, erection, and dismantling expenses.

The cost of a power hoist or derrick with an operator may vary from about \$2 to \$6 per hour, plus transportation, erection, and dismantling expenses.

The cost of scaffolding will vary with the amount required and the type used. Ordinary horse scaffolds (moved by helpers) will cost but a few cents per hour per mason, plus transportation. The cost of pole or post scaffolds, erected and dismantled by helpers, will be the cost of the lumber less salvage value and plus transportation. The cost of post scaffolds will be considerably greater if carpenters are required for erection and dismantling. Cost of post scaffolds may vary from about \$0.75 to \$3 or \$4 per

cubic yard of masonry. Special machine scaffolds may be rented for $4 to $15 per week per machine including transportation, erection, and dismantling.

The total cost of equipment is equal to the sum of the costs of all kinds and types of equipment used on the job.

12. Stonemasonry Estimates.—The cost estimate for stonemasonry may be summarized as follows for each kind of stone and type of work. Unit costs may be per cubic yard, per cubic foot, per square foot or square yard, or per lineal foot as desired.

Item	Unit Cost	Total Cost
Materials (stone and mortar)	$	$
Labor		
Equipment		
Overhead		
Profit		
Total	$	$

The costs of materials, labor, and equipment may be found as directed in the preceding articles. Overhead may be based on the sum of material, labor, and equipment costs or based on labor costs alone. The percentage allowed for overhead may range from about 10 to 25 per cent when based on the sum of the materials, labor, and equipment costs, and from about 25 to 50 per cent when based on labor costs alone. The percentage allowed for profit may vary from 8 to 15 per cent of the sum of all other costs (materials, labor, equipment, and overhead).

13. Illustrative Estimate.—The foundation for a church building 80 ft. long and 40 ft. wide is to be of stonemasonry walls 2 ft. thick and 10 ft. high. The lower 6 ft. of the wall (from bottom to grade) is to be of ordinary flat-stone work and the upper 4 ft. (from grade to top) is to be of coursed granite ashlar. The outside walls above grade are to be pointed smooth, and the inside walls are to be pointed smooth. Prepare a cost estimate for this job, assuming the following:

Ordinary flat stone, per cubic yard	=	$ 8.50
Coursed limestone ashlar, per cubic foot	=	1.85
Mortar mix is 1 to 1 to 3 by volume		
Mortar materials, cement per sack	=	0.70
Hydrated lime per ton	=	18.00
Sand per cubic yard	=	2.10
Mason's wage, per hour	=	1.80
Helper's wage, per hour	=	0.90

Prices given for stone and mortar materials are for these materials delivered at the job.

Materials:

Coursed ashlar will be assumed 1 ft. thick and backed by 1 ft. of rough masonry.

Coursed ashlar $(80 + 80 + 40 + 40) \times 4 \times 1 = 960$ cu. ft., or 35.5 cu. yd.

Assume small waste to equal space of joints.

Then 960 cu. ft. at \$1.85	= \$1,776
Flat stone $(80 + 80 + 40 + 40) \times 6 \times 2$ $+ (80 + 80 + 40 + 40) \times 4 \times 1 = 288 + 960 = 3{,}840$ cu. ft., or 143 cu. yd.	
Of this quantity, about 75 or 80 per cent will be stone and 20 to 25 per cent mortar. Allowing 75 per cent stone and 5 per cent waste yardage of flat stone $= 143 \times 80\% = 115$	
Then 115 cu. yd. at \$8.50	= \$ 978
Total cost of stone	= \$2,754

Mortar required for rough masonry will be about 25 per cent of 143 cu. yd., or 35.8 cu. yd. Mortar for ashlar will be about 5 cu. ft. per cubic yard of masonry, or about 18.5 per cent.

$$960 \text{ cu. ft.} \times 18.5\% = 177.5 \text{ cu. ft., or } 6.6 \text{ cu. yd.}$$

Total amount of mortar = 42.4 cu. yd., say 42.5 cu. yd.

For a 1–1–3 mix by volume, this will require (Table 6-8):

$0.95 \times 42.5 = 40.4$ cu. yd. sand at \$2.10	= \$ 85
$345 \times 42.5 \div 2{,}000 = 7.33$ tons lime at \$18	= 132
$8.60 \times 42.5 = 365$ sacks cement at \$0.70	= 256
Water, say	= 2
Cost of mortar materials	= \$ 475
Cost of stone and mortar	= \$3,229

Labor:

As the walls are not high and stones may be readily handled by hand, all handwork will be assumed. A crew of 3 masons (one acting as straw boss) and 5 helpers will be assumed.

From Table 6-9, this crew should be able to lay about 3×9, or 27, cu. ft. of flat-stone masonry per hour (say 1 cu. yd. per hour, or 1 hr. per cubic yard). For ashlar, the crew rate is about 3×6, or 18, cu. ft. per hour (0.67 cu. yd. per hour, or 1.5 hr. per cubic yard).

Hourly wage of crew $= \$1.80 \times 3 + \$0.90 \times 5 = \$9.90$

Hours for laying stone $= 143 \times 1 + 35.5 \times 1.5 = 143 + 53 = 196$ hr.

Allow about 12 hr. for this crew for cleaning the walls

$$(\text{about } 240 \times 10 + 240 \times 4, \text{ or } 3{,}400 \text{ sq. ft.})$$

and for miscellaneous work. No extra time needs to be allowed for pointing as the joints are struck as the stone is laid.

Total crew time = 208 hr. (624 hr. for masons and 1,040 hr. for helpers)

Total labor cost = \$9.90 × 208 = \$2,059

This may be divided among flat and ashlar masonry according to the hours required for laying, giving about \$555 for the ashlar and \$1,503 for the flat stone, with unit costs of \$15.70 per cubic yard for the ashlar and \$10.50 per cubic yard for the flat stone, based on wall yardage.

Equipment:

The equipment costs will be comparatively small. The equipment, except scaffolding, will be estimated at \$0.10 per hour per mason, plus about \$10 for transportation, or \$0.10 × 3 × 196 + \$10 = \$68

Some horse scaffolding may be needed on the inside of the wall. This may be estimated roughly at about \$20 for the job, including transportation.

Total equipment costs .... = \$68 + \$20 = \$ 88

Overhead. Say 35 per cent of labor costs..... = \$2,059 × 35% = \$721

Profit. Say 10 per cent of sum of \$3,229, \$2,059, \$88, and \$721, or 10 per cent of \$6,097 .... = \$610

Summary:

Item	Cost per Cu. Yd.	Total Cost
Materials	\$18.10	\$3,229
Labor	11.50	2,059
Equipment	0.50	88
Overhead	4.05	721
Profit	3.40	610
Total	\$37.55	\$6,707

If desired, costs per cubic foot may be computed, or costs per cubic foot or per cubic yard for the ashlar and for the rough stone masonry may be determined.

C. CONCRETE BLOCK, BRICK, AND TILE MASONRY

14. Concrete Block, Brick, and Tile.—Concrete block may vary from 4 to 12 in. in height, from 6 to 12 in. in thickness, and from 12 to 32 in. in length. The most common size is $7\frac{3}{4}$ in. high, 8 in. thick, and $15\frac{3}{4}$ in. long (sometimes called 8 by 8 by 16). In addition to the regular or "stretcher" block, there are half blocks, jamb blocks (full and half size), and corner blocks. Concrete block are usually hollow with one or more vertical openings. The common size weigh about 50 to 60 lb. each. Tolerance in dimensions is usually $\frac{1}{8}$ in. in length, $\frac{1}{8}$ in. in height, and $\frac{1}{4}$ in. in width. Concrete block are divided into

three classes according to their strength, *viz.*, heavy-load bearing, medium-load bearing, and nonload bearing.

Concrete tile are usually hollow and vary in height from 3 to 12 in., and in width from 3¾ to 12 in. Their length is usually 12 in. They are classed according to their strength as heavy, medium, and nonload bearing. The nonload-bearing tile may be used for nonload-bearing partitions.

Concrete brick are usually made of standard size (2¼ by 3¾ by 8 in.), are rarely hollow, and may be used in place of the clay brick.

Concrete-trim stone, lintels, and specially molded ornamental work are also made. If desired, the concrete units (block, tile, brick, trim, etc.) may have special facings.

The laying of concrete block and tile will be considered in this section. Concrete or cement brick are laid in the same manner as standard clay brick. Concrete-trim stone and ornamental work are laid in the same manner as ornamental and trim stone and architectural terra cotta.

The mortar used in concrete masonry work of these types is usually a 1 to 3 portland cement and sand mortar, with about 5 to 10 lb. of hydrated lime per sack of cement added to improve the workability.

The joint thickness is usually ¼, ⅜, or ½ in.

The price of concrete block and tile will vary considerably because of the costs of materials, the mix used, the quantity of concrete per unit, the labor wage, and the transportation costs from manufacturer's yard to the job. The price of concrete block may range from about $0.13 to $0.30 each for 8- by 8- by 16-in. block and from $0.08 to $0.20 each for 6- by 8- by 12-in. tile.

In the material take-off, the number of each kind (load or nonload bearing), type (regular, corner, jamb), and size should be listed.

15. Mortar Materials.—A mortar mix of 1 part portland cement to 3 parts sand with 5 to 10 lb. of hydrated lime is often used, though a 1 to 2, 1 to 2½, 1 to 3, 1 to 3½, or 1 to 4 mix may be selected. The proportions may be by volume or by weight, with weight preferred.

The amount of mortar required for 100 concrete block or tile will depend on the size of the unit, the net cross-sectional area of the unit, and the thickness of the joints. From 0.15 to 0.33

cu. yd. of mortar may be needed with an average of about 0.20 to 0.25 cu. yd.

The cost of the mortar materials may range from $0.65 to $1 per sack of cement, from $18 to $35 per ton for hydrated lime, and from $1 to $2.75 per ton or from $1.25 to $3.50 per cubic yard for sand.

Table 6-10 gives the quantities of cement, lime, and sand required for 1 cu. yd. of mortar.

TABLE 6-10.—MORTAR MATERIALS REQUIRED FOR 1 CU. YD. OF MORTAR WITH 10 LB. OF HYDRATED LIME PER SACK OF CEMENT

Mix, cement and sand	Proportions by volume			Proportions by weight		
	Cement, sacks	Lime, lb.	Sand, cu. yd.	Cement, lb.	Lime, lb.	Sand, lb.
1–2	13.00	130	0.96	1,200	130	2,400
1–2.5	10.50	105	0.98	980	105	2,450
1–3	9.00	90	1.00	835	90	2,500
1–3.5	7.75	80	1.00	715	80	2,500
1–4	6.75	70	1.00	625	70	2,500

Sand is estimated at 2,500 lb. per cubic yard.

Approximately 1 cu. yd., or 1.25 tons (2,500 lb.), of sand is required for 1 cu. yd. of mortar.

Diagrams 6-2, 6-3, and 6-4 may be used for estimating the cost of mortar materials. Diagram 6-11 (page 590) may be used for estimating the cost of mortar per 100 block or tile.

The amount of water required per cubic yard of mortar may vary from about 100 to 200 gal. An allowance of a few cents ($0.02 to $0.05) per 100 block or tile, or $0.06 to $0.15 per cubic yard of mortar, is usually sufficient.

16. Labor.—The mason labor required for laying 100 concrete block or tile will vary with the size of the unit, and the number of openings, jogs, corners, etc., in the wall. The mason labor required for pointing the joints will depend primarily on the kind of joints.

The helper labor required per 100 concrete block and tile will depend upon the number laid per hour by the mason and the distance the block and tile have to be moved horizontally and vertically. If the number of units required per hour is quite

or tile, with the size of the regular or "stretcher" block being given.

The costs of materials, labor, and equipment may be found as directed in the preceding articles. Overhead may range from 20 to 50 per cent based on labor costs alone, or from 10 to 25 per cent based on the sum of materials, labor, and equipment costs. Profit may vary from 8 to 15 per cent of the sum of all other costs.

19. Illustrative Estimate.—The walls of a building 60 ft. wide, 150 ft. long, and 12 ft. high are to be constructed of standard-size concrete block $7\frac{3}{4}$ in. high, $15\frac{3}{4}$ in. long, and 8 in. thick. The walls are 8 in. thick. The building is to have 36 steel-sash windows 6 ft. by 8 ft. 6 in., 2 doors 10 by 10 ft., and 3 doors 3 ft. by 7 ft. 4 in. Joints are to be $\frac{1}{4}$ in. thick and are to be struck flush on both outside and inside. Walls are to be brushed. Horse scaffolds are to be used. Block and mortar are to be placed on scaffolds by hand labor. Mortar will be mixed by hand. Mortar mix is 1 part portland cement to 3 parts sand by weight. Hydrated lime to the amount of 10 per cent of the weight of the cement is to be added.

Cost of materials delivered at the job:

Regular or stretcher block, each	$ 0.16
Corner block	0.18
Jamb block, same as regular block	0.16
Half regular and half jamb block	0.10
Lintels, per foot of length	0.12
Sand, per ton	2.00
Cement, per 100 lb. ($0.705 per sack)	0.75
Hydrated lime in sacks, per ton	21.00

Labor wages:

Masons, per hour	$1.65
Helpers, per hour	$0.90

Materials:

Wall area = (150 + 150 + 60 + 60)12 = 5,040 sq. ft.

Openings (6 × 8.5)36	= 1,836			
(10 × 10)2	= 200			
(3 × 7⅓)3	= 66			
Total	= 2,102, say = 2,100 sq. ft.			
Net wall area (outside)	= 2,940 sq. ft.			
Corner block	= 4 × 12 × 12 ÷ 8	= 72 at $0.18		= $ 12.96
Jamb block, doors	= 2 × 2 × 10 × 12 ÷ 8	= 60		
Doors	= 3 × 2 × 7⅓ × 12 ÷ 8	= 66		
Windows	= 36 × 2 × 6 × 12 ÷ 8	= 648		
Total jamb block		= 774		
Full-length jamb block		= 387 at $0.16		= $ 61.92
Half-length jamb block		= 387 at $0.10		= 38.70
Half-length regular block, estimated		= 387 at $0.10		= 38.70

Regular block $= \dfrac{2{,}940 \times 144}{8 \times 16} - \left(72 + 387 + \dfrac{387}{2} + \dfrac{387}{2} - \dfrac{366 \times 12}{16}\right)$

$= 3{,}308 - 846 - 275 = 2{,}087$ at \$0.16 = 349.92

Lintels $= 2 \times 11.33 + 3 \times 4.33 + 36 \times 9.17$

$= 365.67$ ft., say 366 ft. at \$0.12 = 43.92

Total cost of block (about 3,420 of all sizes) = \$546.12

For mortar, allow about 580 lb. sand per 100 block.

Mortar sand required $= \dfrac{580 \times 3{,}700}{2{,}000 \times 100} = 10.75$ tons

Sand = 10.75 tons at \$2.00 = \$21.50

Cement $= \frac{1}{3} \times 10.75 \times 2{,}000$

= 7,170 lb. (763 sacks) at \$0.75 per 100 lb. = 53.75

Lime $= 7{,}170 \times 10\% = 717$ lb. at \$21 per ton = 7.55

Water, say = 2.00

Total cost of mortar materials = \$ 84.80

Total cost of materials (block, lintels, and mortar) = \$630.92

Labor:

Masons' time for laying, pointing, and cleaning wall is assumed at 4.25 hr. per 100 block, as the joints are simple struck joints and cleaning may be by brushing.

Hours for 3,420 block = 145 hr.

Hours for lintels at 3 hr. per 100 ft. (360 ft.) = 20 hr.

Total mason time = 165 hr. at \$1.65 = \$272.55

Helpers' time will be estimated at 1.5 times the masons' time and includes work handling material, mortar, and scaffolding 1.5×165 = 248 hr. at \$0.90 = 223.20

Total labor = \$495.45

Crew may consist of 2 or 4 masons and 3 or 6 helpers, with one mason acting as straw boss.

Equipment:

Equipment required (except scaffolds) will be assumed at \$0.55 per 100 block including transportation.

$\$0.55 \times 34.20 = \$\ 28.80$

Scaffolds are horse scaffolds. Perhaps an estimate of about \$0.15 per 100 block with an allowance of \$10 for transportation will be ample. $\$0.15 \times 34.20 + \$10$ = 15.15

Total equipment costs = \$ 43.95

Overhead:

Overhead will be taken at about $33\frac{1}{3}$ per cent of labor costs.

$\$495.45 \times 33\frac{1}{3}\% = \$165.15$

Profit:

Profit will be assumed at 10 per cent of all other costs.

$(\$630.92 + 495.45 + 43.95 + 165.15) \times 0.10 = \$133.55$

Summary:

Item	Cost per 100 Block	Total Cost
Materials	$17.05	$ 631
Labor	13.40	495
Equipment	1.20	44
Overhead	4.45	165
Profit	3.60	134
Total	$39.70	$1,469

Total number of block is taken as 3,700, considering the lintels to be the equivalent of about 280 block.

D. HOLLOW CLAY TILE (TERRA COTTA) MASONRY

20. Tile Materials.—Clay or terra cotta hollow tile are made of burnt clay. The tile may be glazed or unglazed, and may be classed as wall, partition, furring, or floor tile according to use, and as load- or nonload-bearing tile, depending upon the load carried. Load-bearing tile are usually 8 in. or more in thickness.

Clay wall and partition tile are usually about 12 by 12 in. face size and 3, 4, 5, 6, 8, 10, or 12 in. thick. Other face sizes are 6 by 12, 8 by 12, and 8 by 8 in. Floor tile are usually 12 by 12 in. in size and vary from 2 to 12 in. or more in thickness. Load-bearing tile are heavier than nonload-bearing tile. Many special tile are also made.

Table 6-13 gives approximate weights and costs of partition and wall clay tile. Prices vary greatly at different times and in different parts of the country. Load-bearing tile cost 15 to

TABLE 6-13.—APPROXIMATE WEIGHTS AND COSTS OF HOLLOW CLAY TILE (12- by 12-in. face)

Thickness, inches	Weight per tile, pounds		Cost per 100 tile
	Nonload bearing	Load bearing	
2	12 or 14	.....	$5 –$10
3	14 or 15	.....	5.5– 11
4	16	.....	6 – 12
5	19	.....	7 – 14
6	22	30	8 – 20
7	25	32	9 – 22
8	30	34	10 – 24
9	33	36	12 – 26
10	35 or 36	40–42	14 – 28
12	40	46–52	18 – 32

25 per cent more than partition tile of the same dimensions. Tile with 8- by 8- or 8- by 12-in. faces cost less.

Floor tile will average about the same as to weight and costs as wall tile of equal size. Floor tile may be flat or arched. Forms and centering are often required. See Chap. V on Concrete for methods of estimating forms.

Roof tile or book tile are used on roofs subjected to comparatively light loads. These tile are often 12 by 24 in. in size. They are usually laid on a structural-steel framework.

Furring tile often come in a split form. They are like partition block which are grooved or scored on the sides so that each partition block can be readily split into two halves, each of which is a furring tile.

Fireproofing tile is tile placed around columns and beams for fireproofing purposes. Regular partition tile or special tile may be used.

The number of 12- by 12-in. tile is usually taken equal to the number of square feet of net wall surface to allow for a slight waste and breakage. Net wall surface equals total area of one side of wall less area of openings.

21. Mortar Materials.—The mortar required will vary with the thickness of the tile, the thickness of the joints, and the manner in which the tile is laid (horizontal or vertical). Table 6-14 gives the approximate amounts of mortar required per 100 sq. ft. of tile surface for tile of different thicknesses. Thickness of joints may vary from ¼ to ¾ in., ⅜ or ½ in. thickness being common.

The mortar proportions may be 1 to 2, 1 to 2½, 1 to 3, 1 to 3½, or 1 to 4 by weight or by volume of portland cement and sand. Hydrated lime should be added, say about 10 per cent of the weight of the cement. See Table 6-10 for quantities of cement, lime, and sand per cubic yard of mortar. From 100 to 200 gal. of water should be allowed per cubic yard of mortar. The mortar mix usually used is a 1–3.

The cost of mortar materials will be about as follows: $0.65 to $1 per sack of portland cement, $18 to $35 per ton of hydrated lime, $0.25 to $1 per 1,000 gal. of water, and $1 to $2.75 per ton, or $1.25 to $3.50 per cubic yard of sand.

Diagrams 6-2, 6-3, 6-4, and 6-11 may be used for estimating costs of mortar materials and mortar.

TABLE 6-14.—APPROXIMATE QUANTITIES OF MORTAR FOR 100 SQ. FT. OF SURFACE OR FOR 100 TILE WITH 12- BY 12-IN. FACE

Thickness of tile, inches	Cubic yards of mortar per 100 sq. ft. of surface			
	3/8-in. joints		1/2-in. joints	
	Nonload bearing	Load bearing	Nonload bearing	Load bearing
2	0.05–0.08	....	0.06–0.10	
3	0.06–0.10	....	0.08–0.12	
4	0.08–0.11	....	0.10–0.14	
5	0.10–0.12	....	0.13–0.15	
6	0.12–0.14	0.18–0.24	0.15–0.17	0.23–0.30
7	0.14–0.16	0.20–0.25	0.17–0.20	0.25–0.31
8	0.16–0.19	0.21–0.27	0.20–0.24	0.27–0.34
9	0.18–0.22	0.23–0.30	0.22–0.27	0.30–0.38
10	0.20–0.24	0.26–0.34	0.25–0.30	0.34–0.43
12	0.24–0.29	0.30–0.40	0.30–0.36	0.40–0.50

22. Labor.—The labor required for laying 100 clay tile will vary somewhat with the size and weight of the tile, the number of openings and corners, etc., in the wall, the skill and inclination of the men, etc. One mason can lift and place in the wall tile weighing up to 50 or 60 lb. For heavier tile, two men are often needed. The rate of work (tile laid per hour) does not vary much with the weight of the tile for tile weighing about 40 lb. each or less. The number of helpers required per mason may vary from less than one to about three (usually one to two), depending upon the working conditions at the particular job, the equipment used for mixing mortar and for supplying masons with material, and kind of scaffolding and moves required. On a small job, the crew may consist of 1 to 3 masons with 1 to 6 helpers. On larger jobs where several masons can work without interference, the crew may consist of 1 foreman, 3 to 12 masons, 1 or 2 hoisting engineers, and 6 to 12 helpers. The use of power hoists and power mortar mixers reduces the number of helpers required.

Table 6-15 gives approximate rates of work. Enough helpers and equipment must be provided to keep the masons busy.

Unless otherwise mentioned, all rates are for 12- by 12-in. tile. Time required should be increased 20 to 25 per cent for 8- by 12-in. tile and reduced 15 to 20 per cent for 12- by 24-in. tile. Load-bearing tile are heavier and require a little more time than nonload-bearing tile.

TABLE 6-15.—MASON LABOR REQUIRED FOR LAYING 100 CLAY TILE

Kind of work	Thickness, inches	Hours per 100 tile	Tile per hour
Furring tile	2	2.50– 4.00	25–40
	3	2.85– 5.00	20–35
Wall and partition tile	2	2.85– 5.00	20–35
	3	3.00– 5.00	20–33
	4	3.35– 5.55	18–30
	6	4.00– 6.25	16–25
	8	5.00– 7.15	14–20
	10	5.55– 8.35	12–18
	12	6.25–10.00	10–16
Floor tile	6	2.25– 4.00	25–45
	8	2.50– 4.75	21–40
	10	2.85– 5.55	18–35
	12	3.35– 6.65	15–30
	14	4.00– 8.35	12–25
	16	5.00–10.00	10–20
Fireproofing tile	2, 3, or 4	2.50– 6.65	15–40
Thin glazed floor tile	3⁄8–1⁄2	5–20	5–20

Labor wages are the same as for brick and stone masons and helpers and may vary from $1.25 to $2 per hour for masons and from $0.65 to $1.50 per hour for helpers. Hoisting engineers may cost $1.25 to $2 per hour.

Diagram 6-12 may be used for estimating labor costs when the hourly cost per mason (including helpers, etc.) is known and the hourly output may be reasonably assumed.

23. Equipment.—The equipment required and its cost are practically the same as that needed for brickwork (see Art. 4 of this chapter on Equipment). Power hoists and mortar mixers

should be used when their use will save money and tend to speed up the work. Roughly, the equipment expense will be as follows:

Hand equipment	\$0.15–\$1.00 per 100 sq. ft. (or 100 tile)
Hand hoists	\$0.05–\$0.20 per hour
Small power mortar mixer	\$0.20–\$0.50 per hour
Power hoist or derrick with operator	\$2.00–\$6.00 per hour
Horse scaffolding	\$0.05–\$0.20 per 100 sq. ft. (or 100 tile)
Pole or post scaffolds	\$0.50–\$1.00 per 100 sq. ft. (or 100 tile)
Scaffold machines	\$0.10–\$0.50 per hour

Costs of transportation to and from the job, and erection and dismantling if required, are in addition to the costs mentioned. Elevator towers will cost \$5 to \$10 per foot of height for a one-barrow tower and \$7 to \$14 per foot of height for a two-barrow tower. Salvage values of materials should be deducted and transportation costs added to these values.

24. Clay Tile Masonry Estimates.—The cost estimates for hollow clay tile masonry may be summarized for each kind and size of tile and later totaled as desired. Unit costs may be expressed in costs per 100 sq. ft. of surface or per 100 tile. Overhead should be included and may range from 20 to 50 per cent based on labor costs or from 10 to 25 per cent based on the sum of material, labor, and equipment costs. Profit may range from 8 to 15 per cent of the sum of all other costs.

Item	Cost per 100 Sq. Ft. of Surface or per 100 Tile	Total Cost
Materials (tile and mortar)	\$	\$
Labor		
Equipment		
Overhead		
Profit		
Total	\$	\$

25. Illustrative Estimate.—Prepare an estimate of the cost of constructing partitions of nonload-bearing hollow clay title, 6 by 12 by 12 in. in size. Partitions are four each 9.5 by 24.5 ft. with two openings 4 by 7.5 ft., four each 9.5 by 26 ft. with two openings 4 by 7.5 ft., and eight each 9.5 by 14 ft. with one opening 3.5 by 7 ft.

Cost of materials at job: tile \$10.90 per 100, portland cement \$0.78 per sack, hydrated lime \$0.95 per 100 lb., sand \$1.65 per ton, water \$0.50 per 1,000 gal.

Labor wages are: masons \$1.80 per hour, helpers \$1.00 per hour.

Materials:

Total wall area $= 4(9.5 \times 24.5) + 4(9.5 \times 26) + 8(9.5 \times 14) = 2{,}983$ sq. ft.

Openings $= 8(4 \times 7.5) + 8(4 \times 7.5) + 8(3.5 \times 7) = 676$ sq. ft.

Net wall area $= 2{,}307$

Number of tile $= 2{,}307 + 43$ (say, for breakage) $= 2{,}350$

Cost of tile $= \$10.90 \times 23.50$ $= \$256$

Assuming ½-in. joint, mortar required (see Table 6-14) will be about 0.16 cu. yd. per 100 tile.

For job $0.16 \times 23.07 = 3.70$ cu. yd. Use a 1 to 3 mortar with 10 per cent lime.

Sand (assume 2,600 lb. = 1 cu. yd.)

$$= 3.70 \times \frac{2{,}600}{2{,}000} \times \$1.65 = \$\ 8$$

Cement = 9 sacks per cubic yard

$9 \times 3.70 \times \$0.78 = 26$

Hydrated lime $= 9 \times 10 = 90$ lb. (about).

At \$0.95 per 100 lb., say $= 1$

Water, say $= 1$

Cost of mortar materials $= \$\ 36$

Total cost of materials $= \$292$

The cost of the mortar materials may be checked by Diagrams 6-2, 6-3, and 6-4 if desired.

Labor:

For this type of work, about 5 hr. of masons' time per 100 sq. ft. of wall (or per 100 tile) will be required (Table 6-15). Helpers' time will be about the same.

Masons' cost $= \$1.80 \times 5 \times 23.07 = \$208$

Helpers' cost $= \$1.00 \times 5 \times \$3.07 = \$115$

Labor cost $= \$333$

Checking by Diagram 6-12. $\$0.145 \times 2{,}307 = \$334$.

Equipment:

For this size of job, mortar will probably be mixed by hand.

Equipment, except scaffolds, say $\$0.40 \times 23.07 + \$5$ transportation $= \$14$

Horse scaffolds, say $\$0.13 \times 23.07 + \$3$ transportation $= 6$

Equipment cost $= \$\ 20$

Overhead:

Say about 35 per cent of labor costs, $\$333 \times 35\%$ $= \$117$

Profit:

Say 10 per cent of $(\$292 + \$333 + \$20 + \$117)$ $= \$\ 76$

Total cost $= \$838$

Summary:

Item	Cost per 100 Tile or 100 Sq. Ft.	Total Cost
Materials	$12.65	$292
Labor	14.45	333
Equipment	0.85	20
Overhead	5.05	117
Profit	3.30	76
Total	$36.30	$838

E. GYPSUM BLOCK AND TILE MASONRY

26. Block and Tile Materials.—Precast gypsum tile are used for furring, solid or hollow partitions, fireproofing, and for other purposes. The face of a gypsum block or tile is usually 12 by 30 in., and the thickness may vary from 2 to 8 in. or more.

Table 6-16 gives approximate weights and costs of 100 gypsum block and tile of different thicknesses.

TABLE 6-16.—APPROXIMATE WEIGHTS AND PRICES OF GYPSUM BLOCK AND TILE*

Thickness	Weight, pounds		Cost	
	100 sq. ft.	1 tile	100 sq. ft.	1 tile
2 in. solid	900	2.25	$9–$15	$0.22–$0.37
3 in. solid	1,300	3.25	10– 18	0.25– 0.45
2 in. hollow	700	1.75	8– 14	0.20– 0.35
3 in. hollow	1,000	2.50	9– 16	0.22– 0.40
4 in. hollow	1,300	3.25	10– 18	0.25– 0.45
5 in. hollow	1,550	3.88	11– 20	0.27– 0.50
6 in. hollow	1,800	4.50	12– 22	0.30– 0.55
8 in. hollow	2,300	5.75	14– 25	0.35– 0.62

* Face area = 12 by 30 in. = 2.5 sq. ft.

In the take-off, the wall areas for each kind and thickness of tile are listed and the number of tile of each kind and thickness computed.

27. Mortar Materials.—The mortar materials are gypsum cement and sand. The gypsum cement is sometimes called "gypsum plaster," "patent mortar," "patent plaster," or "prepared mortar." Portland cement may be used in place of gypsum cement, but a portland-cement mortar does not bond well with gypsum tile.

The proportions of the mortar is usually 1 to 3 by volume or weight, with weight preferred. Other mixes used are 1 to 2 and 1 to 2.5.

Table 6-17 gives approximate amounts of mortar required for tile of varying thickness. The thickness of the joints is usually 3/8 or 1/2 in.

TABLE 6-17.—APPROXIMATE QUANTITIES OF MORTAR

Thickness of tile, inches	Cubic yards of mortar for 100 sq. ft.	Cubic yards of mortar for 100 tile
2	0.04–0.05	0.10–0.13
3	0.06–0.075	0.15–0.19
4	0.08–0.10	0.20–0.25
5	0.10–0.125	0.25–0.31
6	0.12–0.15	0.30–0.38
8	0.16–0.20	0.40–0.50

Table 6-18 gives the quantities required per cubic yard of mortar.

TABLE 6-18.—QUANTITIES OF GYPSUM CEMENT AND SAND FOR 1 CU. YD. OF MORTAR

Mix	Mix by volume		Mix by weight	
	Cement, lb.	Sand, cu. yd.	Cement, lb.	Sand, lb.
1–2	1,250	0.93	1,250	2,500
1–2.5	1,040	0.97	1,040	2,600
1–3	900	1.00	900	2,700

Gypsum cement costs $15 to $35 per ton.

Sand costs $1 to $2.75 per ton and $1.25 to $3.50 per cubic yard.

Diagrams 6-2, 6-3, and 6-4 may be used for estimating the costs of mortar materials, and Diagram 6-11 for the cost of mortar per 100 tile.

Water costs $0.25 to $1 per 1,000 gal., and 100 to 200 gal. may be assumed per cubic yard of mortar.

28. Labor.—As gypsum block and tile are fairly light and large compared with hollow clay tile, a mason will lay more square feet of wall per hour with gypsum tile than with hollow clay tile. Consequently, more helpers per mason will be required to keep the masons busy. Usually 1.5 to 2 helpers are required per mason, and 3 may be needed on some jobs. Table 6-19

gives the labor output per mason for laying gypsum block and tile. Face dimensions are 12 by 30 in.

TABLE 6-19.—APPROXIMATE LABOR OUTPUT WHEN LAYING GYPSUM BLOCK AND TILE

Thickness of tile, inches	Mason hours for laying 100 sq. ft.	Square feet per hour per mason	Mason-hours for laying 100 tile	Tile per hour per mason
2	2.0–4.0	25–50	5.0–10.0	10.0–20.0
3	2.1–4.2	24–47	5.2–10.5	9.5–19.0
4	2.3–4.4	23–44	5.7–11.0	9.0–17.5
5	2.5–4.6	22–40	6.2–11.5	8.5–16.0
6	2.8–4.9	20–36	7.0–12.5	8.0–14.5
8	3.3–5.3	18–30	8.2–13.5	7.5–13.5

Labor wages may vary from $1.25 to $2 per hour for masons and from $0.65 to $1.50 per hour for helpers.

Diagram 6-12 may be used for estimating labor costs per 100 tile.

29. Equipment.—The equipment needed will be practically the same as that required for brick masonry and for hollow clay tile masonry. The costs will be practically the same as those given per 100 sq. ft. or per hour in Art. 23 of this chapter. Note that a gypsum tile has a face area of 2.5 sq. ft. compared with 1 sq. ft. for hollow clay tile.

30. Gypsum Block and Tile Estimates.—The cost estimates for this kind of masonry may be summarized for each size of block as directed for other kinds of masonry. About the same percentages for overhead and profit should be allowed as for brick and hollow clay tile masonry.

Item	Cost per 100 Sq. Ft. or per 100 Block	Total Cost
Materials (block and mortar).	$	$
Labor......................		
Equipment..................		
Overhead...................		
Profit.....................		
Total......................	$	$

F. ARCHITECTURAL TERRA COTTA

31. Terra-cotta Materials.—Architectural terra cotta or tile may be hollow or solid. Nearly all larger sizes are hollow,

though the smaller and thinner sizes are solid. This material is used for ornamental molding courses, copings, etc., instead of carved-stone trim. The clay may be molded into almost any desired form or shape. The weight is much less than stone and concrete, being about 70 to 75 lb. per cubic foot.

The usual unit is the cubic foot, though the square foot of surface or the lineal foot may be used if desired. The cost of plain architectural terra cotta will be about the same or a little more than hollow clay tile of equal size and weight. Specially molded terra cotta will cost more. The price of architectural terra cotta is usually quoted at so much per cubic foot and varies with the finish, ornamentation, coloring, difficulty of molding, number of times a piece is duplicated, cost of materials, labor, transportation, etc.

32. Mortar Materials.—The mortar used with architectural terra cotta is usually a 1 to 3 mix by volume or by weight of portland cement and sand. About 10 lb. of hydrated lime per sack of cement is usually added for workability. The addition of coloring matter is necessary if the mortar colors are to agree with colors of the tile. Richer mixes, such as 1 to 2 or 1 to 2½, may be used if desired. Iron or steel dowels and anchors (say one to a block) may be required.

Mortar joints are usually ⅜ or ½ in. in thickness.

The amount of mortar required per 100 cu. ft. of terra-cotta block will vary greatly depending upon the thickness of joints, the size of blocks, and whether or not backing is required. About 0.15 to 0.50 cu. yd. of mortar may be required per 100 cu. ft. of architectural terra cotta. Average values will range from about 0.20 to 0.35 cu. yd. of mortar.

The prices of mortar materials will be the same as those for mortar for clay tile, brick, and stone masonry.

Table 6-8 or 6-10 and Diagrams 6-2, 6-3, and 6-4 may be used for estimating quantities and costs of mortar materials, and Diagram 6-11 for the cost of mortar per 100 cu. ft. of terra-cotta masonry.

33. Labor.—The labor required for laying architectural terra cotta is about the same as for ashlar and cut-stone masonry and for trim-stone masonry. The labor needed will vary considerably with different jobs. One to three helpers will be needed for each mason. Table 6-20 gives approximate labor outputs.

TABLE 6-20.—LABOR FOR 100 CU. FT. OF ARCHITECTURAL TERRA COTTA

Kind of work	Hours per 100 cu. ft.		Cu. ft. per hour	
	Mason	Helper	Mason	Helper
Setting	6–10	9–20	10–17	5–11
Backing	3– 5	3– 5	20–33	20–33
	Hours per 100 sq. ft.		Sq. ft. per hour	
Pointing	1–3	1–2	30–100	50–100
Cleaning	1–3	1–2	30–100	50–100

Labor wages for masons and helpers will be practically the same as for other kinds of masonry, *viz.*, about $1.25 to $2 per hour per mason and $0.65 to $1.50 per hour for helpers. Diagram 6-12 may be used for estimating labor costs.

34. Equipment.—The equipment required will be about the same as that needed for brick and stone masonry. A hoist should be provided when the size of the job, number and weight of block, and vertical distance to be lifted warrants its use. Scaffolding will usually be needed and may be horse, pole or post, or machine scaffolds.

The cost of the kinds of equipment used will be about the same as that for the equipment used for brick and stone masonry.

35. Architectural Terra Cotta Estimates.—Cost estimates for architectural terra cotta estimates may be itemized and summarized as for other types of masonry. Overhead costs may range from 20 to 50 per cent of the labor costs and profit from 10 to 25 per cent of the sum of all other costs.

Unit costs may be per 100 cu. ft., per 100 sq. ft., per 100 lin. ft., per 100 block, or per cubic yard as desired.

Item	Unit Cost (per 100 Cu. Ft.)	Total Cost
Materials (block and mortar)	$	$
Labor		
Equipment		
Overhead		
Profit		
Total	$	$

CHAPTER VII

DAMPPROOFING AND WATERPROOFING

1. Dampproofing and Waterproofing.—The cost of dampproofing or waterproofing a surface will depend on the kind of surface to be treated or covered, the method of treatment used, the degree of dampproofing or waterproofing desired, the physical conditions of the particular job, and the wages, working conditions, skill and inclination of the workers.

In general, dampproofing is intended to resist dampness and not to resist water pressure. Waterproofing is intended to resist water pressure. The materials should preferably be applied to the exterior or water side of a wall or floor.

The four methods commonly used for dampproofing or waterproofing surfaces are the following:

1. Painting with a water-resisting or -repellant paint or compound. One or more coats may be used.

2. Plastering with water-resisting mortar or compound, usually ½ in. or more in thickness.

3. Placing membranes or layers of waterproofing materials on the surface or between two thicknesses of the masonry or wall material.

4. Integral waterproofing by adding powders or compounds to the concrete or mortar to make it more dense, and more water resisting.

The unit of measurement is usually the square yard or the square of 100 sq. ft. when referring to a surface, or the 100 lin. ft. when referring to the filling of cracks or the dampproofing or waterproofing of narrow strips.

The take-off should list the type of treatment, kind of surface to which the treatment is to be applied, and other necessary data.

2. Materials.—Among the paints or compounds applied in the same manner as a paint for the purpose of dampproofing are

For example, the labor required per square for applying a three-ply membrane and asphalt waterproofing might be (0.8 hr. per coat × 4 coats asphalt) + (0.8 hr. per layer of membrane × 3 layers), or a total of 3.2 + 2.4 or 6.0 labor-hours per square.

Diagram 7-4 (page 595) may be used for estimating labor costs per square when the hourly wage is known and the hourly output may be reasonably assumed.

4. Equipment.—The equipment needed will depend upon the kind of waterproofing or dampproofing material used and the method of application.

For cleaning, good stiff brushes are usually sufficient unless the surface must be washed also.

For drying, some form of artificial heat, say a blowtorch, may be used.

For painting, mixing cans, brushes, ladders, planks, sawhorses, and painters' small tools may be needed.

For plastering, plasterers' small tools and ladders, sawhorses, and plank for light scaffolds will be required.

For applying membranes, about the same equipment will be needed as for painting.

For integral waterproofing, usually no extra equipment is required for adding the waterproofing material either to the cement or to the mixing water.

An allowance from a dollar or two up to $25 or $30, depending on the particular job, may be sufficient for equipment costs.

5. Overhead and Profit.—Overhead costs may vary from about 20 to 40 per cent of the labor cost, or from 12 to 25 per cent of the sum of labor and material costs.

Profit may range from about 8 to 20 per cent of the sum of all other costs.

6. Dampproofing and Waterproofing Estimates.—Estimates for these kinds of work should include costs of all materials at the job, of all labor, of equipment required, and of overhead and profit. Unit costs per square should be computed, and total costs should be computed and tabulated.

7. Illustrative Estimate.—Prepare an estimate of the cost of waterproofing a basement wall of concrete for a basement 24 by 40 ft. in size and 8 ft. high. Specifications require two layers of felt and three coats of asphalt to be used. Each layer of felt must weigh 25 lb. per square, and each coating of asphalt must average 35 lb. per square. Price of felt is

\$3.20 per 100 lb. and that of asphalt is \$0.42 per gallon at the job. Labor wages are \$1.35 per hour. Overhead is 28 per cent of the labor cost, and profit is assumed at 9 per cent of all other costs.

Materials:	
Wall surface (24 + 40)2 × 8 = 1,024 sq. ft. = 10.24 squares.	
Felt, 2 layers, allow 12 per cent for laps.	
2 × 25 × 1.12 × 10.24 = 575 lb.	
Cost at \$3.20 per 100 lb.	= \$ 18.40
Check with Diagram 7-3	
Diagram gives \$0.90 per layer per square, and for \$0.90 × 2 layers × 10.24 squares = \$18.45	
Asphalt, 3 coats 35 lb. per coat = 105 lb. per square	
105 × 10.24 = 1,075 lb.	
One gallon = 9.5 lb., gallons needed = 113.5	
Cost at \$0.42 per gallon	= 47.70
Check with Diagram 7-2. 1 gal. = 9.5 lb.	
Cost per pound = \$0.42 ÷ 9.5 = \$0.04425, or \$4.425 per 100 lb.	
Diagram gives \$1.55 per coat per square	
\$1.55 × 3 coats × 10.24 squares = \$47.70	
Total materials	= \$ 66.10
Labor:	
Assume 0.9 hr. per coat or per layer per square	
Labor-hours = 0.9 × 5 coats and layers × 10.24 sq. = 46 hr.	
Labor cost = \$1.35 × 46	= 62.10
Check with Diagram 7-4. Cost per square = \$1.21	
\$1.21 × 5 coats × 10.24 squares = \$62.10	
Equipment, say about \$7 for this job	= 7.00
Overhead, 28 per cent of \$62.10	= 17.40
Profit, 9 per cent of \$152.60	= 13.75
Total estimated cost	= \$166.35

Or a cost per square of \$166.35 ÷ 10.24 = \$16.25

CHAPTER VIII

WOOD CONSTRUCTION

A. CLASSES AND ESTIMATES

1. Classification.—Wood construction may be classified according to type of structure or to kind of work. Different types of structures would be mill buildings, bridges, towers, barns, stores, residences, forms, scaffolding, etc. Different kinds of work would be heavy framing, light framing, flooring, planking, sheathing, exterior finishing, and interior finishing. Perhaps a classification as to kinds of work is more suitable for estimating, though an estimate is usually prepared for one certain structure. In this text, wood construction will be classed as follows:

1. Heavy construction, such as mill buildings and trusses.
   a. Heavy framing.
   b. Planking.
2. Light construction, such as ordinary wooden buildings.
   a. Rough carpenter work, including framing, sheathing, rough flooring and roofing, furring, door and window frames, and insulation.
   b. Finish carpenter work.
      (1) Exterior finish, including siding, cornice, porches, doors, windows, etc.
      (2) Interior finish, including finish, flooring, doors, windows, stairs, cupboards, trim, etc.

Wood-lathing estimates are discussed in Chap. XI on Lathing and Plastering, wooden shingles in Chap. X on Roofing and Flashing, and forms for concrete in Chap. V on Concrete.

2. Estimates.—Estimates for wood construction may be divided into materials, labor, plant or equipment, overhead, and profit. The estimate for any particular structure may be prepared as the estimator desires. For example, in estimating the cost of wood construction for a residence, one estimator might list all materials and all labor separately; a second estimator

might divide the materials and labor into rough work and finish work, and then estimate the costs (materials, labor, and perhaps equipment and overhead) for each of these two kinds of work separately. A third estimator might divide the work farther, say into (1) framing; (2) sheathing, rough flooring, and roofing; and (3) other rough carpenter work; (4) exterior finish; (5) interior finish except cabinetwork; and (6) cabinetwork. He might then estimate the materials, labor, and perhaps equipment and overhead for each of these divisions.

3. Materials.—The materials included in wood-construction are the various kinds of lumber and the necessary nails, screws, bolts, and other hardware. Most lumber is measured by the board foot, which is equivalent to a piece of wood 1 ft. square and 1 in. thick. The number of board feet in a piece of lumber is equal to one-twelfth of the product of the width in inches by the thickness in inches by the length in feet. For example, the number of board feet in a 2- by 10-in. joist 12 ft. long is $2 \times 10 \times 12/12$, or 20 board feet, or as usually stated, 20 ft. b.m. Molding, trim, and many special shapes are measured by the lineal foot.

All material sawed from logs is called lumber. The larger sizes are called timbers, and the timbers may be resawed to obtain smaller sizes. Rough edge is lumber sawed on two sides. Planed resawed lumber is called dressed lumber. Dressed planks and boards free from all defects are called clear. Lumber may also be classed as No. 1 or No. 2 common, depending on the comparative number, kinds, and sizes of defects.

Rough sawing to standard size means that the timbers will not be over 1/4 in. scant from the actual size specified; *i.e.*, a 12-by-12 timber shall not measure less than 11 3/4 by 11 3/4 in.

Standard dressing shall mean that not more than 1/4 in. shall be allowed for dressing each surface; *i.e.*, a 12-by-12 timber after dressing in all four sides will not measure less than 11 1/2 by 11 1/2 in.

Standard lengths are multiples of 2 ft., and usually range from 10 to 20 ft. Longer and shorter lengths are special. Fractional lengths are counted as of the next higher standard length.

Standard widths are in multiples of 1 in.

Sizes usually quoted are 1 by 6, 1 by 8, 2 by 4, 2 by 6, 2 by 8, 2 by 10, 2 by 12, 3 by 12, 6 by 12, and 12 by 12 in.

There are several classifications of lumber such as kind of wood, (pine, oak, fir), grading (select, common), manufacture or sawing, size, and use. The size classification is as follows:

Yard lumber and structural timber:

1. Strips. Less than 2 in. thick and under 8 in. wide.
2. Boards. Less than 2 in. thick and 8 in. or over in width.
3. Dimension. Any width, and 2 in. and over, but under 7 in., in thickness.
   a. Planks, 2 in. and under 4 in. thick, and 8 in. or more wide.
   b. Scantlings, 2 in. and under 6 in. thick, and less than 8 in. wide.
   c. Heavy joists, 4 in. and under 6 in. thick, and 8 in. or more wide.
4. Timbers (structural). Six inches or larger in least dimensions.

Joists and plank are usually 2 to 4 in. thick and 4 in. or more in width.

Beams and stringers are usually 5 in. or more thick and 8 in. or more in width.

Posts, sills, and timbers are usually 6 by 6 in. or larger in size.

The grading classification is briefly as follows:

1. Select lumber that is generally clear and suitable for finishing.
   First class is suitable for natural finishes and includes grades A and B.
   Second class is suitable for paint finishes, and includes grades C and D.
2. Common lumber containing defects making it unsuitable for finishes.
   First class is suitable for use without waste. Grades are Nos. 1 and 2 common.
   Second class is suitable for use with waste. Grades are Nos. 3, 4, and 5 common.
   Common native lumber is sometimes called N. C.

Table 8-1 gives the number of feet, board measure, for the more common sizes of lumber for lengths from 8 to 24 ft.

TABLE 8-1.—FEET BOARD MEASURE

	Length in feet								
	8	10	12	14	16	18	20	22	24
	Feet, board measure								
1 by 4	2⅔	3⅓	4	4⅔	5⅓	6	6⅔	7⅓	8
1 by 6	4	5	6	7	8	9	10	11	12
1 by 8	5⅓	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
1 by 10	6⅔	8⅓	10	11⅔	13⅓	15	16⅔	18⅓	20
1 by 12	8	10	12	14	16	18	20	22	24
2 by 4	5⅓	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
2 by 6	8	10	12	14	16	18	20	22	24
2 by 8	10⅔	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
2 by 10	13⅓	16⅔	20	23⅓	28⅔	30	33⅓	36⅔	40
2 by 12	16	20	24	28	32	36	40	44	48
2 by 14	18⅔	23⅓	28	32⅔	37⅓	42	46⅔	51⅓	56
2 by 16	21⅓	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
3 by 6	12	15	18	21	24	27	30	33	36
3 by 8	16	20	24	28	32	36	40	44	48
3 by 10	20	25	30	35	40	45	50	55	60
3 by 12	24	30	36	42	48	54	60	66	72
3 by 14	28	35	42	49	56	63	70	77	84
3 by 16	32	40	48	56	64	72	80	88	96
4 by 4	10⅔	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
4 by 6	16	20	24	28	32	36	40	44	48
4 by 8	21⅓	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
4 by 10	26⅔	33⅓	40	46⅔	53⅓	60	66⅔	73⅓	80
4 by 12	32	40	48	56	64	72	80	88	96
4 by 14	37⅓	46⅔	56	65⅓	74⅔	84	93⅓	102⅔	112
4 by 16	42⅔	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
6 by 6	24	30	36	42	48	54	60	66	72
6 by 8	32	40	48	56	64	72	80	88	96
6 by 10	40	50	60	70	80	90	100	110	120
6 by 12	48	60	72	84	96	108	120	132	144
6 by 14	56	70	84	98	112	126	140	154	168
6 by 16	64	80	96	112	128	144	160	176	192
8 by 8	42⅔	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
8 by 10	53⅓	66⅔	80	93⅓	106⅔	120	133⅓	146⅔	160
8 by 12	64	80	96	112	128	144	160	176	192
8 by 14	74⅔	93⅓	112	130⅔	149⅓	168	186⅔	205⅓	224
8 by 16	85⅓	106⅔	128	149⅓	170⅔	192	213⅓	234⅔	256
10 by 10	66⅔	83⅓	100	116⅔	133⅓	150	166⅔	183⅓	200
10 by 12	80	100	120	140	160	180	200	220	240
10 by 14	93⅓	116⅔	140	163⅓	186⅔	210	233⅓	256⅔	280
10 by 16	106⅔	133⅓	160	186⅔	213⅓	240	266⅔	293⅓	320
12 by 12	96	120	144	168	192	216	240	264	288
12 by 14	112	140	168	196	224	252	280	308	336
12 by 16	128	160	192	224	256	288	320	352	384

Diagrams 8-1 and 8-2 (pages 596 and 597) show the relations between size, length, and board feet of lumber.

The approximate weights of lumber are given in Table 8-2. These weights are for seasoned lumber with moisture content 15 to 20 per cent or less. Weights of green lumber may be from 20 to 35 per cent more. When computing weights per 1,000 ft. b.m., some allowance was made for sawing and dressing.

TABLE 8-2.—APPROXIMATE WEIGHTS OF LUMBER

Kind of lumber	Lb. per cu. ft.	Lb. per 1,000 ft. b.m.	
		Rough sawed	Dressed
Cedar	23	1,800	1,650
Cypress	30	2,300	2,150
Fir, Douglas	32	2,500	2,300
Fir, eastern	26	2,000	1,850
Gum	36	2,800	2,550
Hemlock	28	2,150	2,000
Locust	45	3,450	3,200
Mahogany	36	2,800	2,550
Maple, hard	43	3,300	3,050
Oak, red	40	3,100	2,850
Oak, white	45	3,450	3,200
Pine, red	30	2,300	2,150
Pine, white	25	1,950	1,800
Pine, yellow longleaf	42	3,250	3,000
Pine, yellow shortleaf	36	2,800	2,550
Poplar	30	2,300	2,150
Redwood, California	25	1,950	1,800
Spruce	26	2,000	1,850
Walnut	36	2,800	2,550

When estimating quantities of lumber required for any particular purpose, allowance must be made for waste in cutting, matching, sawing, planing, manufacture, lapping, etc. This allowance may vary from about 5 per cent for end cutting up to 40 per cent or more for lapping siding. Approximate allow-

ances for waste will be given for different kinds of lumber in the following articles.

The prices asked for lumber will vary greatly as to locality, kind of wood, size of lumber, manufacture, finish, etc. Prices are usually quoted in dollars per 1,000 ft. b.m., though trim and special types may be priced per lineal foot. At the present time (1946), prices may vary from $35 to $90 per 1,000 ft. b.m. for the smaller sizes of No. 2 common grade up to about $130 per 1,000 ft. b.m. for No. 1 common timbers. Hardwood flooring may vary from about $90 to $200 per 1,000 ft. b.m. according to locality and kind and grade of lumber. When preparing estimates, the estimator must be sure that his prices are correct.

Allowance must be made in the materials estimate for all construction and builders ironwork and hardware, and for the nails, screws, and bolts required. The ironwork and hardware are usually listed from the plans and specifications. The weights of the various items of structural ironwork may be found from any good structural-steel handbook, or the weights may be computed from the dimensions and the weight per cubic foot (iron weighs 450 lb. per cubic foot, and steel 490 lb. per cubic foot). The price is usually given per pound (or per 100 lb.) and may vary from about $0.03 to $0.06 or $0.07 per pound.

Builders hardware such as hinges, locks, handles, and stops should be listed separately and prices obtained from dealers or from catalogues.

The quantities of nails are usually estimated at so many pounds per 1,000 ft. b.m. or at so many pounds per square of 100 sq. ft., consideration being given to the size of the lumber and kind of construction.

The prices of wire nails may vary from about $0.03 to $0.06 per pound. Extra prices are charged for the smaller sizes. Wire nails usually come in kegs weighing 100 lb. Table 8-3 gives the sizes of wire nails, their lengths, and numbers per pound. In general, the length of nail should be from 1½ to 2 times the thickness of the lumber. The quantity required will vary considerably with the thickness of lumber and kind of work. Further information in regard to quantities of nails required will be given in later articles.

When preparing the take-off, the materials may be classified as suggested in the article on Classification. Then all the kinds of

wood, sizes, and dimensions may be listed under the appropriate headings. Hardware and structural ironwork may be listed separately. Nails, screws, and bolts are usually estimated after the lumber has been listed, consideration being given to the kind of construction. If available, a "reminder" list, such as described in Chap. XIX on Complete Estimates and in Appendix A, should be used so that no important items will be omitted.

TABLE 8-3.—WIRE NAILS. LENGTH AND APPROXIMATE NUMBER PER POUND

Size	Length, inches	Common	Finish
2d	1	875	
3d	1.25	575	
4d	1.50	320	575
5d	1.75	255	
6d	2	200	300
7d	2.25	155	
8d	2.50	110	190
9d	2.75	90	
10d	3	72	135
12d	3.25	60	
16d	3.50	47	
20d	4	30	
30d	4.5	23	
40d	5	18	
50d	5.5	14	
60d	6	11	

4. Labor.—The classes of labor used in wood construction will include superintendents, carpenter foremen, finish carpenters, rough carpenters, handy men, apprentices, and helpers or laborers. The class of labor and number in each class will depend on the size and kind of job, men available, and local and union regulations. In general, both skilled and unskilled labor should be used. The laborers should be grouped in gangs in such a manner that the work will go forward efficiently in regard to cost, quality, and quantity. A gang may consist of a foreman, carpenters, handy men, helpers, and apprentices.

The number of labor-hours required for a job will depend on the amounts and kinds of work, the working conditions, and the skill and inclination of the workmen and foreman.

The labor cost will depend upon the hourly wages and the labor-hours required.

Labor wages vary considerably in different localities and at different times. Wages are usually higher in the larger cities. Approximate ranges of hourly wages in 1946 are as follows:

Kind of Labor	Hourly Wage
Foremen	\$1.50–\$3.00
Carpenters	1.25– 2.25
Handy men	0.75– 1.75
Helpers	0.65– 1.25
Apprentices	0.65– 1.25
Operators for hoists, derricks, etc	1.50– 2.25

5. Equipment.—The number and kinds of tools will vary considerably, depending on the size and kind of the job. Practically all jobs will require hand tools such as a carpenter has in his tool chest. Such hand tools include saws, hammers, planes, chisels, squares, and planes. If hand tools are to be provided by the contractor, an allowance of a few cents (say from \$0.03 to \$0.10) per labor-hour should be sufficient. Most carpenters have their own hand tools. Practically every job will require some sawhorses and benches. An allowance of a few dollars per job for transportation and depreciation is usually enough for sawhorses and benches.

On larger jobs, power saws (both portable and stationary), power drills, planers, and other power tools may be efficiently used. Such tools may cost from a few cents up to a dollar or more per hour for depreciation, repairs, and power (if power operated). Costs of operator and of transportation to and from the job should be added when necessary. Small derricks or hoists (either hand or power) may be needed on larger jobs. These hoists and derricks may cost from a few cents up to several dollars per hour. Such costs should include depreciation, repairs, and maintenance, transportation to and from job, power (if used), and operators. If electric power is used, the costs of running power lines and for providing the necessary switches, fuses, meters, etc., must be included. The following figures are approximate. Costs of transportation, erection, moving, and

take-down costs should be added. If special operators are used, their wages must be added.

Tool	Hourly Cost
Portable electric saw	$0.10–$0.35
Power drills	0.10– 0.40
Stationary saws (bench)	0.20– 0.60
Stationary planers (bench)	0.25– 0.75
Hand hoists and derricks	0.05– 0.30
Small power hoists	0.15– 0.60
Larger power hoists	0.25– 1.00
Power derrick and cranes	1.00– 4.00
Elevating tower	0.50– 5.00

6. Overhead and Profit.—Overhead costs should include all cost items such as were listed in Art. 12 of Chap. I. The overhead may be based as a percentage on the sum of the costs of materials, labor, and equipment, or may be based on labor costs alone. When based on the material, labor, and equipment costs, overhead costs may range from 15 to 35 per cent; and when based on labor costs alone, overhead may vary from 25 to 55 per cent. Unemployment insurance, social security taxes, and government regulations all tend to raise overhead costs.

The percentage allowed for profit on wood construction may range from 5 to 15 per cent of the sum of all other costs.

7. Summary.—The costs of wood construction may be estimated in as much detail as desired, such as heavy and light construction, rough and finish carpenter work, framing, flooring, roofing, and interior finishing. Some estimators work out their costs per 1,000 ft. b.m. The total and unit costs may be summarized as follows:

Item	Unit cost (Usually per 1,000 Ft. B.M.)	Total Cost
Materials	$	$
Labor		
Equipment		
Overhead		
Profit		
Total	$	$

B. HEAVY WOOD CONSTRUCTION

8. Materials.—The materials used in heavy wood construction are wooden timbers and planks, construction steel and iron-

work, and spikes, screws, bolts, etc., for fastening the materials together.

The estimating of the quantities of materials in this type of construction is a fairly simple process. However, if, in the take-off, the length and other dimensions of each piece of framing are listed, together with the number and type of cuts and holes, the estimating of the labor will be aided. In the listing of the planking, it is often advisable to state the spacing of the supporting beams so that the pounds of spikes required may be more accurately estimated.

The take-off may be divided into general divisions such as framing timbers, planking, steel and iron work, and spikes, screws, and bolts. The framing timbers will include such items as sills, columns and posts, girders, and beams in mill buildings and chords, web members, and cross bracing in bridges and trusses. The planking will include plank for flooring, which may or may not be tongued and grooved. The construction steel and iron work will include such items as iron and steel column caps and bases, beam hangers, fishplates, tie rods, and beam boxes.

Allowance must be made for waste in the manufacture, cutting, and use of lumber. For heavy framing, if the sticks are listed to the nearest commercial size, an allowance of about 5 or 8 per cent is usually sufficient for end cutting. For heavy planking, both end and side waste must be allowed for. End waste will average about 5 or 6 per cent, and may be more if supports are spaced so that standard lengths cannot be used. Side waste will vary with the width of the plank and may be about 10 per cent for plank 8 in. wide, about 13 per cent for plank 6 in. wide, and about 19 or 20 per cent for plank 4 in. wide. Hence, for plank 6 in. wide, the total waste would be about 5 plus 13, or 18 per cent.

9. **Labor.**—The labor for heavy wood construction may be divided into the work of preparing the timbers and the work of erecting or placing the prepared timbers in position. On some jobs, as in the construction of wood mill buildings, the work of erection may be divided into the work of hoisting and that of placing and securing or fastening the timbers. Power tools, such as saws, drills, planers, and hoists should be used to reduce labor time whenever practical.

The labor for heavy wooden framing may be estimated in hours per 1,000 ft. b.m., due consideration being given to the sizes of the pieces and the sawing, cutting, hoisting, and fastening to be done. A better and more accurate way is to estimate the labor in hours per piece or stick (sill, column, or beam), due consideration being given to the size of the stick and the number of operations required. After the labor-hours, using the piece as a unit, have been estimated, the labor-hours per 1,000 ft. b.m. may be computed.

The labor for planking may be estimated in hours per square or per 1,000 ft. b.m., consideration being given to the thickness and width of the plank, the spacing of the supports, and the amount of end cutting required. A portable power saw should be used to reduce the time required for end sawing.

The labor for structural ironwork may be estimated in hours per piece. Frequently this labor is included in the labor of erection. Base plates are usually set by a mason and helper. From 0.50 to 1.50 labor-hours will be required per base plate.

TABLE 8-4.—APPROXIMATE LABOR-HOURS FOR PREPARING TIMBERS

Kind of work	Labor-hours per operation		
	Small timbers	Medium timbers	Large timbers
End cutting, hand tools	0.3 –0.5	0.5 –1.0	0.8 –1.2
End cutting, power tools	0.2 –0.3	0.3 –0.6	0.4 –0.7
Ripping, lineal foot, hand tools	0.1 –0.3	0.2 –0.4	0.3 –0.5
Ripping, linear foot, power tools	0.1 –0.2	0.1 –0.3	0.2 –0.4
Chamfering, lineal foot	0.01–0.03	0.01–0.03	0.02–0.03
Drilling 1-in. or smaller holes, hand drill	0.02–0.05	0.03–0.06	0.04–0.09
Drilling 1-in. or smaller holes, power drill	0.02–0.03	0.02–0.04	0.03–0.05
Drilling 1.5-in. holes, hand drill	0.03–0.07	0.04–0.09	0.06–0.12
Drilling 1.5-in. holes, power drill	0.02–0.04	0.03–0.06	0.04–0.08
Cutting V notches	0.2 –0.3	0.3 –0.4	0.4 –0.5
Cutting square notches	0.2 –0.4	0.3 –0.5	0.4 –0.6
Cutting mortises	0.1 –0.2	0.1 –0.3	0.2 –0.4

When preparing mill timbers, each carpenter may work alone if the timbers are small, in gangs of two carpenters or of one carpenter and one helper if the timbers are of medium or average

size, and in larger gangs for the larger timbers if more than two men are required for handling the timbers.

Table 8-4 gives approximate labor-hours for different operations. For each operation, some of the time will be required for handling the timber, as well as for completing the operation. Sometimes the handling when power tools are used requires more time than when hand tools are used. Small timbers are less than about 100 sq. in. in cross section, medium timbers 100 to about 180 sq. in., and large timbers over 180 sq. in. in cross section. This division as to size is approximate.

The gang required for hoisting timbers will depend on whether a hand or power hoist or derrick is used and also on the size of the timber. A hand derrick or hoist may be used for structures up to 30 or 40 ft. in height. A power hoist or derrick may be used for any height.

A typical gang for a hand hoist or derrick may consist of
- 1 foreman.
- 4 laborers for operating derrick.
- 1 laborer for guy line.
- 2 carpenters for placing and fastening timber.

A typical gang for a power hoist or derrick may consist of
- 1 foreman.
- 1 operator or engineer.
- 2 laborers for loading (one may also tend guy).
- 2 carpenters for placing and fastening timber.

Sometimes, as in the construction of a multistoried building, a power hoist or derrick is used for hoisting timbers to the floor level, and one or more gangs with hand derricks are used for the erection. The personnel of the gangs may be varied for most efficient working. The load for a hand derrick is usually one timber, though two smaller timbers may be hoisted at times. The load for a power derrick is usually larger and may consist of 1 or 2 large timbers, 2 to 4 medium timbers, or 2 to 6 or 8 small timbers.

The erection time required per timber will be about the same for timbers of less than about 400 ft. b.m. Larger timbers may require a little more time, a larger gang, or both. The total time required per timber will consist of loading time, hoisting, unloading or placing, and moving derrick.

Loading	1– 3 min.
Unloading and placing timber, hand hoist	3– 5 min.
Unloading power hoist or derrick	About 1 min. per timber
Placing timber	2– 4 min.
Hoisting, hand	2– 5 ft. per minute
Hoisting, power	5–20 ft. per minute
Moving small derrick	10–30 min.
Moving large derrick	30–90 min.

The work should be planned so that the derrick or hoist moves will be a minimum. The average moving time per timber should not exceed 5 min., and should be kept to about 2 or 3 min. when practical. The load of a hand derrick will usually be one timber, and the load of a power derrick may be 1, 2, 3, or more timbers, depending on timber size and derrick capacity.

A hand derrick will handle up to about 400 ft. b.m. per load, and a power derrick will usually handle larger loads, say up to 800 or 1,200 ft. b.m., depending on the capacity of the derrick.

Plank will ordinarily require no preparation, but may be hoisted in suitable loads and then spiked in place. The expense of hoisting plank will depend on the size of load, speed, vertical distance, times for loading and unloading derrick, and times for moving derrick.

TABLE 8-5.—APPROXIMATE POUNDS OF SPIKES REQUIRED FOR PLANKING

Thickness of plank, in.	Width of plank, in.	Spacing of supports, ft.					Labor-hr. per 100 sq. ft.		
		4	6	8	10	12	Tongue and grooved	Splined	Laminated
		Spikes, lb. per 100 sq. ft.							
2	4	4.5	3.3	2.2	1.8	...	3.5–5.0		
	6	3.0	2.2	1.5	1.2	...	2.5–3.5		
	8	2.3	1.7	1.1	0.9	...	2.0–3.0		
3	4	15.5	11.5	7.5	6.5	...	4.0–5.0	5.0–6.0	
	6	10.5	8.0	5.5	4.5	...	3.0–4.0	4.0–5.0	
	8	8.5	6.0	4.2	3.5	...	2.5–3.5	3.5–4.5	
4	6	....	11.5	8.0	6.5	5.7	3.5–5.0	4.5–6.0	6.0–8.0
	8	....	8.5	6.0	5.0	4.3	3.0–4.5	4.0–5.5	5.0–7.0

The labor of placing and spiking plank will vary somewhat with the thickness and width of plank, spacing of supports, and work-

ing conditions. In general, the labor-hours required per 100 sq. ft. of floor will be about the same. For example, as the distance between supports increases, the amount of spiking will decrease and the difficulties of placing the plank and of working will increase.

Table 8-5 gives approximate labor-hours and pounds of spikes required per 100 sq. ft. of floor area. Lengths of spikes are 3.5, 5.5, and 7 in. for 2-, 3-, and 4-in. plank, respectively.

Table 8-6 gives approximate times in labor-hours for hoisting and erecting timber and plank. The times given include a reasonable allowance for moving the derricks. The height of one story may be taken as varying from 10 to 16 ft. Labor-hours are given per timber and per 100 sq. ft. of floor area for plank. Timber hoisting includes loading and hoisting with hand derrick and loading, hoisting, and unloading with power derrick. When a power derrick is used, timbers are raised to floor level by power derrick and then raised in place by hand derrick and crew. Planks are raised to floor level and unloaded and then placed and spiked by carpenters.

Whenever possible, the labor should be analyzed in detail, and per timber rather than per 1,000 ft. b.m.

For example, an 8- by 8-in. column 12 ft. long containing 64 ft. b.m. might require 0.4 labor-hour for end cuts, 1.0 labor-hour for chamfering, and 1.1 labor-hours for hoisting and erecting, giving a total of 2.5 labor-hours per timber or about 39 labor-hours per 1,000 ft. b.m. However, a 16- by 16-in. column 12 ft. long containing 256 ft. b.m. (four times as much as the 8 by 8) might require 1.2 labor-hours for end cuts, 1.0 labor-hour for chamfering, and 1.8 labor-hours for hoisting and erecting, giving a total of 4 labor-hours per timber, or about 15.5 labor-hours per 1,000 ft. b.m.

For another example, compare the labor-hours required for a large girder for the second floor and a small crossbeam for the fifth. The larger girder is a 12- by 16-in. timber 20 ft. long containing 320 ft. b.m. Labor-hours might be 2.0 for end cuts, 0.8 for chamfering, and 1.7 per hoisting and erecting, giving a total of 4.5 labor-hours per timber, or about 14 labor-hours per 1,000 ft. b.m. The smaller beam is 8 by 12 in., 10 ft. long, and contains 80 ft. b.m. Labor-hours might be 1.0 for end cuts, 0.4 for chamfering, and 1.4 for hoisting and erecting, giving a

TABLE 8-6.—APPROXIMATE LABOR-HOURS FOR HOISTING AND ERECTING TIMBERS AND PLANK

Timber	Load	Hoisting: One story	Hoisting: Two stories	Hoisting: Additional story	Erection or placing and fastening
Hand Derrick, 400 Ft. B.M. Capacity Labor-hours per timber					
Small...........	One	1.00	1.50	0.50	0.50
	Two	0.60	0.90	0.30	0.50
Medium.........	One	1.10	1.65	0.55	0.55
Large...........	One	1.20	1.80	0.60	0.60
Labor-hours per 100 sq. ft. floor area					
2-in. plank.......	400 ft. b.m.	1.20	1.60	0.40	3.00
3-in. plank.......	400 ft. b.m.	1.50	2.10	0.60	3.50
4-in. plank.......	400 ft. b.m.	1.80	2.60	0.80	4.00
Labor-hours per 1,000 ft. b.m.					
2-in. plank.......	400 ft. b.m.	5.00	6.60	1.60	12.5
3-in. plank.......	400 ft. b.m.	4.20	5.80	1.60	9.8
4-in. plank.......	400 ft. b.m.	3.75	5.35	1.60	8.4
Power Derrick, 1,000 Ft. B.M. Capacity Labor-hours per timber					
Small	One	0.70	0.90	0.20	0.80+0.50
	Two	0.40	0.50	0.10	
	Three	0.30	0.37	0.07	
	Four	0.25	0.30	0.05	
	Five	0.21	0.25	0.04	
	Six	0.18	0.21	0.03	
Medium	One	0.80	1.00	0.20	0.90+0.55
	Two	0.45	0.55	0.10	
	Three	0.35	0.42	0.07	
Large	One	0.90	1.10	0.20	1.00+0.60
	Two	0.50	0.60	0.10	
Labor-hours per 100 sq. ft. of floor area					
2-in. plank.......	1,000 ft. b.m.	0.95	1.10	0.15	3.00
3-in. plank.......	1,000 ft. b.m.	1.15	1.40	0.25	3.50
4-in. plank.......	1,000 ft. b.m.	1.30	1.60	0.30	4.00
Labor-hours per 1,000 ft. bm.					
2-in. plank.......	1,000 ft. b.m.	3.50	3.70	0.20	12.5
3-in. plank.......	1,000 ft. b.m.	2.80	3.00	0.20	9.8
4-in. plank.......	1,000 ft. b.m.	2.20	2.40	0.20	8.4

total of 2.8 labor-hours per timber, or about 35 labor-hours per 1,000 ft. b.m.

Hence, from these two examples alone, the labor-hours for 1,000 ft. b.m. may vary from 14 to 40, which indicates that labor estimates based on 1,000 ft. b.m. will probably be unreliable. In general, the larger the timber, the less the labor-hours required per 1,000 ft. b.m. For a rough estimate, the labor-hours per 1,000 ft. b.m. may be assumed to vary from 40 to 85 for timbers containing 60 to 400 ft. b.m., with an average value of about 20 labor-hours per 1,000 ft. b.m.

TABLE 8-7.—APPROXIMATE LABOR-HOURS PER 1,000 FT. B.M. IN HEAVY WOOD CONSTRUCTION

Member	Timber size	Labor-hours per 1,000 ft. b.m.
Mill building	Small	25–45
	Medium	20–35
	Large	15–25
Roof trusses	Medium and small	30–45
Trestles	Medium and small	15–30
Waling	Large	15–30
	Medium	20–40
Waling	Remove	3– 7
Hoisting tower	Small	25–50
Material storage bin	Small and plank	20–40
Post scaffold	Small	12–25
	Remove	5–10
Plank	2 in.	14–22
	3 in.	12–18
	4 in.	10–15

The data given in Table 8-7 has been gleaned from various sources, and is approximate only. The labor-hours given are for preparing or framing and hoisting and erecting. It is assumed that most of the work of preparing the timbers will be done on the ground or floor where some power tools are available. If the work of preparing the timbers must be done by hand after the timbers are hoisted, the values given in the table shuld be increased from 50 to 100 per cent. The plank are assumed to be hoisted to the floor and then cut, placed, and spiked.

A statement concerning labor wages is given in Art. 4 of this chapter.

Labor Diagrams.—Diagrams 8-3 and 8-4 (pages 598 and 599) may be used for estimating labor costs of preparing, hoisting, and erecting timbers.

Diagrams 8-5 and 8-6 (pages 600 and 601) may be used for estimating the labor cost per 100 sq. ft. as for planking.

Diagrams 8-7 and 8-8 (pages 602 and 603) may be used for approximate estimates of labor costs per 1,000 ft. b.m. for heavy wood construction.

10. Equipment.—The equipment or plant required for heavy wood construction will include most of the ordinary carpenter's hand tools and several power tools, such as saws, drills, and planers. Hand or power hoists and derricks will be required on nearly all jobs.

The capacity of a hand derrick is usually about 400 ft. b.m., and that of a power derrick is usually larger, say 600 to 1,200 ft. b.m. The hoisting rates may vary from 2 to 5 ft. per minute for hand derricks and from 5 to 20 ft. per minute for power derricks. An operator is usually provided for a power derrick.

See Art. 5 of this chapter for approximate costs of equipment. When computing equipment costs per hour or per 1,000 ft. b.m., the estimator must include depreciation, transportation to and from the job, erection and removal, maintenance, and operation costs. If the equipment is rented, the estimator must know just what costs are included in the rental prices. When electric power is to be used, the cost of providing this power (power lines, switches, fuses, meter) must be included.

11. Heavy Wood Construction Estimates.—The cost estimates for heavy wood construction should be computed and then summarized as directed in Art. 7 of this chapter. As mentioned in Art. 6, overhead expenses may range from 15 to 35 per cent of all costs or from 25 to 55 per cent of the labor costs. Profit may range from 5 to 15 per cent.

12. Illustrative Estimates.—The illustrative estimates following show the methods of preparing estimates for this kind of construction. The material prices, labor-hours, wages, equipment costs, etc., assumed in these problems may or may not apply to other jobs, because of differences in working conditions, prices, wages, foremen, and of skill and inclination of workmen.

Illustrative Estimate.—Estimate the cost of constructing a hoisting tower for one hoist, exclusive of the hoist, cable, and pulleys. Platform hoist is 7 ft. square. The four corner posts and two guide posts are to be of 4- by 6-in. timbers. Diagonal braces are 1- by 6-in. rough lumber. Horizontal braces are 2 by 6 in. Sills are 6 by 8 in. (two 4- by 6-in. timbers) resting on a bed of 2-in. plank. The top of tower (cat head) is to be covered with 2-in. plank, and four 4 by 8 crossbeams are to be provided. Height of tower is to be 45 ft. Tower is to have four guy wires. Lumber, No. 1 common, costs \$80 per 1,000 ft. b.m. delivered on the job.

Materials:

Plank for top and base, say 64 × 2 or 128 ft. b.m. and 81 × 2 or 162 ft. b.m. for base, plus about 10 per cent for waste, say	320 ft. b.m.
Sills, about 2 × 4 × 8, or 64 lin. ft. of 4 by 6, say	130 ft. b.m.
Posts, about 6 × 44, or 264 lin. ft. of 4 by 6, say	550 ft. b.m.
Horizontal braces, about 24 pieces each 8 ft. long, or 192 lin. ft. of 2 by 6, say	200 ft. b.m.
Diagonal braces, about 48 pieces, each 10 ft. long, or 480 lin. ft. of 1 by 6, say	250 ft. b.m.
Top crossbeams, four 4- by 8-in. beams each 8 ft. long, or 32 lin. ft., say about	90 ft. b.m.
Total	1,540 ft. b.m.
Four guy wires each 80 ft. long, say 320 ft. of ⅜-in. wire or	120 lb.
Spikes and bolts, with some waste, say	30 lb.
Cost of material = 1.54 × \$80 + \$9.00 (spikes and wire) say	\$132

Labor:

Labor-hours required may be somewhere from 14 to 26 per 1,000 ft. b.m. or from 22 to 40 for this job if power drills and saws are available. If no power tools are used, the labor-hours may vary from about 25 to 50 per 1,000 ft. b.m. or from 40 to 80 for the job. This is not very accurate, so a rough estimate of the labor required for each part of the work will be made. It will be assumed that no power tools are available, and that the gang consists of 2 carpenters and 2 helpers.

	Hours
Arrange base plank and construct sill	4
End cutting posts, say 48 cuts	8
Cutting horizontal braces, say 30 cuts	3
Erecting posts and braces by hand	40–48
Placing plank and beams at top	4
Attaching guy wires	3
Total labor-hours	62–70

Say two 8-hr. days for the 4-man gang, or 64 labor-hours.

Cost of gang with carpenters at \$2 per hour and helper at \$1.25 per hour is \$6.50 per hour.

Cost of gang for two 8-hr. days is \$6.50 × 16, or	\$104
This is equal to \$67.50 per 1,000 ft. b.m.	
Equipment:	
Equipment used will be ordinary carpenter's hand tools, which are owned by the men, and a few sawhorses and benches. For the equipment and its transportation, allow	\$20
Overhead:	
About 30 to 35 per cent of labor costs should be sufficient, say 35. \$104 × 35% is	36
Profit:	
If profit is to be charged, say 10 per cent of all other costs, or	29
Total cost	\$321

Illustrative Estimate.—Estimate the cost of the columns, girders, and planking for a two-story mill building 40 by 48 ft. in size. Columns are spaced 10 ft. on centers crosswise of the building and 8 ft. on centers lengthwise of the building, giving 5 × 7, or 35, columns per floor. Girders run crosswise of the building, and are approximately 10 ft. long, with 4 × 7, or 28, girders per floor required. Planking is 3 in. thick and is laid lengthwise of the building. First floor is concrete. Girders for second floor are 10 by 14 in. in size. First-story columns are 10 by 10 in. in size and 12 ft. long. Second-story columns are 8 by 8 in. in size with outer columns 12 ft. long, intermediate columns 13 ft. long, and center columns 14 ft. long. Roof girders are 8 by 12 in. in size and are covered with plank 2.5 in. thick. Steel base plates for the columns have been set by the concrete contractor. Column caps are of steel costing \$2.95 each. Lumber for framing costs \$96 per 1,000 ft. b.m. and 6-in. plank \$90 per 1,000 ft. b.m. delivered at the job. Labor wages are foreman \$3, carpenter \$2, and helper \$1.20 per hour.

Materials:

Columns, first story $35 \times 12 \times \frac{10 \times 10}{12} = 3{,}500$ ft. b.m. at \$96 =	\$ 336
Columns, second story $(14 \times 12 + 21 \times 14) \times \frac{8 \times 8}{12}$ = 2,464 ft. b.m. at \$96 =	237
Note that 14-ft. timbers must be purchased and then cut for the intermediate columns.	
Girders, second floor $28 \times 10 \times \frac{10 \times 14}{12} = 3{,}267$ ft. b.m. at \$96 =	314
Girders, roof $28 \times 10 \times \frac{8 \times 12}{12} = 2{,}240$ ft. b.m. at \$96 =	215
Plank, floor, and roof, allow 18 per cent for end and side waste, and assume roof area 42 by 50 to allow for slope and overhang $(40 \times 48 \times 3 + 42 \times 50 \times 2.5)1.18 = 13{,}000$ ft. b.m. at \$90 =	1,170
Column caps $2 \times 35 \times \$2.95$ =	206
Spikes, with some allowance for waste, say 7.5 lb. per 100 sq. ft. of floor area or 25.5 lb. per 1,000 ft. b.m. of plank. $25.5 \times 13 = 333$ lb. at \$0.06 =	20
Bolts, etc., at about 3 lb. per girder, $3 \times 56 = 168$ lb. at \$0.06 =	10
Total materials (24,471 ft. b.m. of lumber) =	\$2,508

Labor:

Gangs. For preparing the timbers, laborers will be arranged in gangs of two, each gang consisting of two carpenters.

For erection, one gang consisting of 1 foreman, 4 laborers on windlass and derrick, 1 laborer on guy rope, and 2 carpenters putting timbers in place. Average wage of gang = $(3.00 + 2 \times 2.00 + 5 \times 1.20)\frac{1}{8}$, or \$1.62.

For laying the plank, carpenters will be used in gangs of two.

Columns. Preparation. Each will require 2 end cuts and chamfering on 4 edges for preparation. Assume 0.8 hr. for 2 end cuts and 1.0 hr. for chamfering, giving a total of 1.8 hr. labor per column.

Erection. First-floor columns may be erected without hoisting, allowing about 0.75 labor-hours for each. Second-story columns will have to be hoisted, allowing about 1.50 labor-hours for hoisting and placing and proportionate part of time for moving derrick.

Labor for preparation	$= 70 \times 1.8$	= 126 hr. at \$2	= \$ 252
Labor for erection, first story	$= 35 \times 0.75$	= 26 hr. at \$1.62	= 42
Labor for erection, second story	$= 35 \times 1.50$	= 53 hr. at \$1.62	= 86
Labor cost of columns			= \$ 380

This is equal to a cost of \$380 ÷ 7.0, or about \$54 per 1,000 ft. b.m., and 205 ÷ 7.0 (about 7,000 ft. b.m.), or about 29 hr., per 1,000 ft. b.m.

Girders for second floor. Preparation. Allow 1.0 labor-hour for 2 end cuts, 0.15 hr. for drilling 6 bolt holes, and 0.4 hr. for chamfering 2 edges, giving a total of 1.55 hr. per girder.

Erection. Allow about 1.50 labor-hours for each hoisting, placing, fastening, and proportionate time of moving derrick.

Labor for preparation	$= 28 \times 1.55 = 44$ hr. at \$2	= \$ 88
Labor for erection	$= 28 \times 1.50 = 42$ hr. at \$1.62	= 68
Labor cost of second-floor girders		= \$ 156

This is equal to a cost of \$156 ÷ 3.3 or about \$48 per 1,000 ft. b.m. and 86 ÷ 3.3 or about 26 labor-hours per 1,000 ft. b.m.

Girders for roof. Preparation. Allow 1.50 labor-hours. Timbers are smaller but end cuts are a little harder.

Erection. Allow about 2.00 labor-hours for each for hoisting, placing, fastening, and derrick moves.

Labor for preparation	$= 28 \times 1.50 = 42$ hr. at \$2	= \$ 84
Labor for erection	$= 28 \times 2.00 = 56$ hr. at \$1.62	= 90
Labor cost for roof girders		= \$ 174

This is a cost of \$174 ÷ 2.24, or about \$78, per 1,000 ft. b.m. and 98 ÷ 2.24, or about 43 labor-hours, per 1,000 ft. b.m.

Total labor cost of girders = \$156 + \$174 = \$ 330

Planking for floor. Area $= 40 \times 48 = 1{,}920$ sq. ft. or 19.2 squares

Allow 1.50 labor-hours for hoisting per square, then hoisting labor $= 1.50 \times 19.2 = 29$ hr. at \$1.62 = \$ 46

Allow 3.50 labor-hours for placing and spiking, by carpenters. $3.50 \times 19.2 = 67$ hr. at \$2 = \$ 134

Planking for roof. Area = 42 × 50 = 2,100 sq. ft. or 21 squares.	
Allow 1.80 labor-hours for hoisting per square; hoisting labor = 21 × 1.80 = 38 hr. at $1.62	= $ 62
Allow 3.25 labor-hours for placing and spiking by carpenters, 3.25 × 21 = 68 hr. at $2	= 136
Total labor cost for planking	= $ 378
This is a cost of about $9.40 per square or $29 per 1,000 ft. b.m.	
Labor-hours are 202 total, or about 5 per square or about 15.5 per 1,000 ft. b.m.	
Total labor = $380 + $330 + $378	= $1,088

Equipment:

The equipment used will be the ordinary carpenters' hand tools, one hand derrick, and perhaps a small portable power drill and one or two small electric power saws.

Total cost of equipment may be assumed at about $40 for derrick, $40 for electric tools and power, $30 for small tools, $30 for benches and sawhorses, plus $30 transportation = $ 170

Overhead:

Somewhere between 25 to 40 per cent of labor costs may be assumed for this kind of work, say 33 per cent, $1,088 × 33 % = $ 360

Profit:

Assumed at 10 per cent of all other costs (2,508 + 1,088 + 170 + 360) × 10 % = $ 413

Summary:

The estimate may be summarized as follows.

The unit costs are based on 24.500 ft. b.m. of lumber

Item	Cost per 1,000 Ft. B.M.	Total Cost
Materials	$102.35	$2.508
Labor	44.40	1,088
Equipment	6.95	170
Overhead	14.70	360
Profit	16.85	413
Total	$185.25	$4.539

C. LIGHT WOOD CONSTRUCTION—ROUGH WORK

13. Light Wood Construction.—As stated in Art. 1 of this chapter, light wood construction refers to the construction of such structures as ordinary wooden frame stores, barns, residences, apartments, and of buildings about three stories or less in height in which the timbers used are usually less than about 40 sq. in. in cross section and are rarely over 2 or 3 in. thick, with the exception of a few sills, posts, or beams.

Light wood construction may be divided into rough and finish carpenter work. This section discusses rough work, and the following section, finish work.

14. Materials.—The materials for the rough carpenter work of light wood construction may be classified as follows:

Framing. Sills, studs, joists, rafters, plates, beams, posts, ribbons.

Boarding, sheathing, flooring, roofing.

Furring and grounds.

Door and window frames (if installed by rough carpenters).

Insulation.

In the materials take-off, the sizes and lengths of all lumber should be listed and then computed and totaled in board feet or lineal feet. Almost all lumber for rough carpenter work is priced per 1,000 ft. b.m. Any lumber less than 1 in. thick is classed as 1 in. thick. The use of a good reminder list, such as is described in Appendix A, is helpful in avoiding errors caused by omissions.

Framing.—Sills may be scaled from the plans. These may be single sticks or may be built up from 2-in. material. Sills may be 6 by 6, 6 by 8, 6 by 10, etc., in size. When estimating sills, about 6 in. should be allowed for lapping single sticks, and about 5 per cent allowed for end waste. Sill plates may be used when the walls extend all around the building and offer a firm support. Sill plates may be 2 by 6, 2 by 8, or 2 by 10 in size.

The number, size, and length of posts supporting floor beams or joists may be taken from the plans. Common sizes of wooden posts are 6 by 6, 6 by 8, and 8 by 8. About 5 per cent may be allowed for waste. In some instances, cast-iron or structural-steel posts are used.

In some cases, heavy floor beams may be used for supporting the joists. These beams may be single piece, though they are usually built up of 2-in. material. Common sizes are 6 by 8, 6 by 10, 6 by 12, 8 by 8, 8 by 10, 8 by 12, 10 by 10, and 10 by 12.

Ordinary plates and caps, placed below and on top of studs, are usually 2-in. material of the same width as the studs.

Wall and partition studs should be listed as to size and length. These studs are usually 2 by 4 in. in size and spaced 16 in. on centers, though 2 by 3 and 2 by 6 are sometimes used, and spacings may be 12, 20, or 24 in. One extra stud is usually provided at each corner and at each opening. About 5 per cent should be allowed for end waste.

A rule for finding the number of wall studs required, spaced 16 in. on centers, is to:

1. Take three-fourths of total length of walls in feet.
2. Add one stud for each length of wall.
3. Add one stud for each intersection with partition.
4. Add two studs for each wall opening.
5. Add, for plates and caps, twice the total length of wall divided by height of studs.
6. Add 5 per cent for waste.

For finding the number of partition studs spaced 16 in. on centers:

1. Take three-fourths of total lengths of partitions in feet.
2. Add one stud for each length of partition.
3. Add one stud for each partition intersection.
4. Add two studs for each partition opening.
5. Add, for plates and caps, twice the total length of partition divided by the height of studs.
6. Add 5 per cent for waste.

An approximate rule is to allow 1.25 studs for each foot of length of wall and partition.

Joists should be listed according to size and length. They are usually spaced 16 in. on centers. Ordinary sizes of joists are 2 by 6, 2 by 8, 2 by 10, and 2 by 12, though 3-in. material is sometimes used. To find the number of joists, divide the length of floor perpendicular to the joist by 1⅓ ft. (16 in.) and add one end joist. Also add one joist for each partition and header, as joists are usually placed in pairs under partitions and when headers or short crossbeams frame into them. Allow 5 per cent for end waste.

Bridging is usually required for all joists. At least one pair of bridging is used between each two joists. Bridging is usually made of 1-by-3 or 1-by-4 strips. The length of each piece will vary according to the spacing and depth of the joists. About 18 in. may be allowed for each piece when joists are spaced 16 in. on centers.

Rafters are usually 2 by 6, 2 by 8, or 2 by 10, though 2 by 4 and 2 by 12 have been used, depending on inclination of roof, span, spacing, and load. The spacing is usually 16 in. or 2 ft. The size, length, and number of rafters should be listed in the take-off. Allow 5 per cent for end waste on ordinary roof work. If there is much special framing as for gables, the waste may be more, say as much as 10 per cent in some instances.

Ribbons are usually 1 by 4, 1 by 5, or 1 by 6. The length should be scaled from the plans. Usually one line of ribbons around the walls is required for each story. Ribbons are sometimes included with furring and grounds.

Rough Boarding and Sheathing.—Rough boarding or sheathing for floors, walls, and roof may be of unmatched boards 1 by 6, 1 by 8, or 1 by 10 in size or of matched boards (tongue and grooved or shiplap) 1 by 6, 1 by 8, 1 by 10, or 1 by 12 in size. Rough flooring may be laid across the joists or diagonally. Wall sheathing may be placed horizontally or diagonally. Rough roofing is usually placed across the main rafters. No allowance is usually made for small openings in floors or roofs. Small wall openings are not allowed for, and large openings (doors and windows) may or may not be deducted. Some estimators consider the waste in wall sheathing as being equal to the openings, and others allow for waste and deduct for the larger openings. The use of ordinary boards and shiplap for outside wall sheathing is decreasing. Fiberboard, pressed wood, etc., is being used instead.

Table 8-8 gives approximate allowance for end and side waste for material and unmatched boards laid on floors, walls, and on flat roofs. For pitched roofs and for gables, add 5 per cent more. Wall openings for windows and doors are deducted.

TABLE 8-8.—ALLOWANCE FOR WASTE IN ROUGH BOARDING

Size, inches	Unmatched		Matched	
	Laid crosswise	Laid diagonal	Laid crosswise	Laid diagonal
1 by 6	15	20–25	20	25–30
1 by 8	13	18–22	18	22–28
1 by 10	11	15–20	16	20–25
1 by 12	10	15–20	15	20–25

Diagram 8-9 (page 604) may be used for estimating the cost of rough boarding and sheathing.

Furring and Grounds.—Furring and grounds are usually about 1 by 2 or 1 by 3 in size. The lengths are scaled from the plans. Furring and grounds are usually listed in lineal feet instead of

board feet. Approximately 2 lin. ft. of grounds are required for each linear foot of base or chair rail, and 1 lin. ft. of grounds for each linear foot of picture mold or casing.

Window and Door Frames.—The window and door frames are often set by the rough carpenters as soon as the framing and sheathing permits and, consequently, are included with the rough carpenter work. In some cases, these frames are not set until the finish carpenter work is started, and then this work is included in the finish carpenter work.

In the take-off, the window and door frames are listed as separate units according to size.

Insulation.—Insulating material is of two kinds, that which is placed between the studs or joists, and that which is placed outside the studs either on the outside to take the place of the rough sheathing or on the inside to take the place of the lath.

Insulating material that is placed between the studs or walls usually comes in strips of suitable width for studs or joints spaced 16 in. on centers and in various lengths. Some of the softer material comes in rolls. The total length should be given, with an allowance of about 5 per cent for laps and waste. Some insulating material comes in blocks or bats about 15 in. wide and of varying lengths and should be listed as to number of units of a given length or as to total length. Other material comes loose and is sold by the pound or cubic foot, 1 cu. ft. being enough for an area of 3 or 5 sq. ft. between joists.

Insulating material that is to be placed on the outside of the joists usually is in widths of 32 or 48 in. and in lengths from 6 to 12 ft. The thickness is usually ⅝ or ¾ in. This material is listed and priced per 1,000 sq. ft. of surface. There are many varieties on the market. When this material is used for outer sheathing, it is usually placed by the rough carpenters and classed as rough carpenter work. When it is used instead of lath, it may be placed by rough carpenters or by lathers and classed accordingly. When it is used as interior finish, it is placed by finish carpenters and classed as interior finish. Waste, when classed as rough carpenter work should be small, say 5 per cent. No deductions should be made for small openings, but large openings (ordinary windows and doors) should be deducted. There are many varieties of plywood or wallboard or plaster board on the market. Prices for this type of material vary from

TABLE 8-9.—UNITS OF MEASUREMENT, APPROXIMATE WASTE, AND NAILS REQUIRED

Material	Unit of measurement	Percentage of waste	Pounds of nails
Framing:			
Sills, single piece	1,000 ft. b.m.	5	5–10
Sills, built up	1,000 ft. b.m.	5– 8	10–20
Posts	1,000 ft. b.m.	5	None
Beams, built up	1,000 ft. b.m.	5– 8	10–25
Studs	1,000 ft. b.m.	5	10–15
Plates and caps	1,000 ft. b.m.	5– 8	10–20
Joists	1,000 ft. b.m.	5	10–25
Bridging	1,000 ft. b.m.	5–10	20–25
	1,000 lin. ft.	2– 5	5– 8
Rafters, simple roofs	1,000 ft. b.m.	5– 8	8–15
Rafters, gables and dormers	1,000 ft. b.m.	10–20	10–20
Ribbons	1,000 ft. b.m.	5– 8	20–25
	100 lin. ft.	2– 4	1– 2
Boarding, flooring, and sheathing:			
Rough flooring, unmatched			
Laid crosswise	1,000 ft. b.m.	15	20–30
Laid diagonal	1,000 ft. b.m.	20–25	20–30
Rough flooring, matched			
Laid crosswise	1,000 ft. b.m.	20	20–30
Laid diagonal	1,000 ft. b.m.	25–30	20–30
Roofing, unmatched			
Flat and plain	1,000 ft. b.m.	15–20	20–30
Pitched, gables	1,000 ft. b.m.	20–30	20–30
Roofing, matched			
Flat and plain	1,000 ft. b.m.	20–25	20–30
Pitched, gables	1,000 ft. b.m.	25–30	20–30
Wallboard, plaster board, etc	1,000 sq. ft.	5–10	12–20
Sheathing, unmatched			
Laid crosswise	1,000 ft. b.m.	15	20–30
Laid diagonal	1,000 ft. b.m.	20–25	20–30
Sheathing, matched			
Laid crosswise	1,000 ft. b.m.	20	20–30
Laid diagonal	1,000 ft. b.m.	25–30	20–30
Miscellaneous:			
Furring and grounds	100 lin. ft.	8–12	1– 2
Window and door frames	Unit	.....	1– 2

about $30 and up per 1,000 sq. ft.; average prices for plaster and wall board material ordinarily used vary from about $30 to $80 per 1,000 sq. ft., depending on kind, quality, and thickness.

Miscellaneous material may be listed according to article, weight, length, area, or volume as the case may be.

Nails.—The nails used should be from about 1.5 to 2 times the thickness of the board. At least two nails should be allowed for each board at each support. Boards over 8 in. wide will require three or more nails at each support. The waste in nails is comparatively large. From 10 to 25 per cent may be allowed for this purpose.

The information given for materials for rough carpenter work is summarized in Table 8-9.

15. Labor. *Framing.*—The labor time for framing light wood construction will vary with the times required for preparing and erecting each piece. These times will vary according to the number and kind of cuts required per piece, size of piece, and difficulties of erection. Consequently, some estimators prefer to estimate light wood framing, using a piece (or 100 pieces) as a unit and others use 1,000 ft. b.m. as a unit.

Table 8-10 gives the carpenter-hours required for light framing, using the piece as a unit. Cutting will require about two-thirds of the time required for preparation and measuring and laying out about one-third. The values given in the table are for softer woods such as hemlock, spruce, and soft pine. From 15 to 25 per cent more time must be allowed for preparing harder woods such as hard pine, chestnut, and oak. The time required for preparing the timbers depends on the cuts required and not on the length of the piece. If templates can be used, considerable time may be saved in laying out and measuring.

For bridging between joists, allow 2 to 4 labor-hours per 100 pieces.

The times given are carpenter-hours if no helpers are used. On work where helpers may be used, the times given are man-hours.

Diagrams 8-3 and 8-4 may be used for estimating labor costs per timber for light framing.

Table 8-11 gives approximate times in man-hours required for light framing, using 1,000 ft. b.m. as a unit. Usually one half to two-thirds of the time will be for preparation (measuring, laying

TABLE 8-11.—APPROXIMATE TIME IN MAN-HOURS PER 1,000 FT. B.M. FOR LIGHT FRAMING

Kind of timber	Hours per 1,000 ft. b.m.		
	Preparation	Erection	Total
Sills, single piece	12–18	8–12	20–30
Built up	15–25	8–12	25–35
Posts, single piece	8–12	8–12	16–24
Girders, single piece	12–18	10–15	24–35
Built up	15–25	10–15	27–40
Joists, 2 by 6, 2 by 8, 2 by 10	12–18	9–15	22–33
2 by 12, and larger	10–15	8–12	18–27
Ceiling beams, 2 by 4, 2 by 6, 2 by 8	15–20	10–16	25–35
Bridging, per 1,000 pieces	10–15	10–15	20–30
Per 1,000 ft. b.m.	30–40	30–40	60–80
Studs, wall, 2 by 4, 2 by 6	12–25	8–12	18–37
Partition, 2 by 3, 2 by 4, 2 by 6	12–25	8–15	20–40
Plates and caps	.....	.....	20–40
Ribbons, 1 by 4, 1 by 5	.....	.....	30–50
Rafters, main	10–20	10–15	20–35
Jack	15–25	12–20	25–40
Hip and valley	20–30	15–30	30–45
Small roof trusses	25–30	15–20	40–50

TABLE 8-12.—APPROXIMATE MAN-HOURS FOR ROUGH BOARDING AND SHEATHING

Work	Hours per square of 100 sq. ft.	Hours per 1,000 ft. b.m.
Rough flooring, unmatched, crosswise	1.6–2.9	14–25
Diagonal	2.1–3.5	17–29
Matched, crosswise	1.9–3.3	16–27
Diagonal	2.4–4.0	19–31
Roofing, unmatched, plain and flat	2.0–3.0	17–25
Gables and dormers	2.7–4.0	22–32
Matched, plain and flat	2.3–3.5	19–28
Gables and dormers	3.0–4.5	24–35
Sheathing, unmatched, crosswise	1.8–3.0	16–26
Diagonal	2.3–3.7	19–30
Matched, crosswise	2.0–3.5	17–29
Diagonal	2.5–4.1	20–32
Wallboard and plaster board	1.5–2.8	14–26

may be the square of 100 sq. ft. or 1,000 ft. b.m. A square will require more than 100 ft. b.m. on account of waste. When wall or plaster board is used for rough sheathing, the time required is usually less than for rough boarding. Approximate time in man-hours for rough boarding and sheathing is given in Table 8-12.

Some estimators add 1 hr. of labor for every 8 to 12 lin. ft. of hip, ridge, and valley in the roof, and 1 to 2 ft. b.m. of lumber for each lineal foot of roof hip, ridge, and valley.

Diagrams 8-5, 8-6, 8-7, and 8-8 may be used for estimating labor costs of rough boarding and sheathing.

Miscellaneous.—There is always more or less miscellaneous labor connected with the rough carpenter work which cannot be readily classified with other labor and, consequently, should be listed separately. Table 8-13 gives approximate man-hours required for several items of work.

TABLE 8-13.—APPROXIMATE MAN-HOURS FOR MISCELLANEOUS WORK

Kind of Work	Man-hours	
Furring on wood	1 –2	per 100 lin. ft.
Furring on brick and tile	1.5–3	per 100 lin. ft.
Grounds on wood	2 –5	per 100 lin. ft.
Grounds on brick and tile	5 –6	per 100 lin. ft.
Insulating material, between studs	2 –8	per 100 lin. ft.
Insulating material, between joists	2 –6	per 100 lin. ft.
Setting single outside door frames	1.5–2.5	each
Setting single inside door frames	1 –3	each
Setting double inside door frames	2 –3	each
Setting single window frames	1.0–1.5	each
Setting double window frames	1.5–2.0	each
Setting triple window frames	2.0–3.0	each
Cutting holes and fitting plugs in masonry walls	2.5–5.0	for 10
Bridging	2 –4	per 100 pieces
Building paper	0.8–1.5	per 100 sq. ft.

Diagrams 8-5 and 8-6 may be used for estimating furring and grounds, etc., using rate of work per 100 lin. ft. instead of 100 sq. ft.

16. Equipment.—The equipment used for rough carpenter work in light wood construction often consists of hand tools only, of which each carpenter should have a set. Sometimes workbenches, power bench saws, and portable electric saws may be used to advantage. If electric power is to be used, the

may be the square of 100 sq. ft. or 1,000 ft. b.m. A square will require more than 100 ft. b.m. on account of waste. When wall or plaster board is used for rough sheathing, the time required is usually less than for rough boarding. Approximate time in man-hours for rough boarding and sheathing is given in Table 8-12.

Some estimators add 1 hr. of labor for every 8 to 12 lin. ft. of hip, ridge, and valley in the roof, and 1 to 2 ft. b.m. of lumber for each lineal foot of roof hip, ridge, and valley.

Diagrams 8-5, 8-6, 8-7, and 8-8 may be used for estimating labor costs of rough boarding and sheathing.

Miscellaneous.—There is always more or less miscellaneous labor connected with the rough carpenter work which cannot be readily classified with other labor and, consequently, should be listed separately. Table 8-13 gives approximate man-hours required for several items of work.

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Grounds on wood	2 –5	per 100 lin. ft.
Grounds on brick and tile	5 –6	per 100 lin. ft.
Insulating material, between studs	2 –8	per 100 lin. ft.
Insulating material, between joists	2 –6	per 100 lin. ft.
Setting single outside door frames	1.5–2.5	each
Setting single inside door frames	1 –3	each
Setting double inside door frames	2 –3	each
Setting single window frames	1.0–1.5	each
Setting double window frames	1.5–2.0	each
Setting triple window frames	2.0–3.0	each
Cutting holes and fitting plugs in masonry walls	2.5–5.0	for 10
Bridging	2 –4	per 100 pieces
Building paper	0.8–1.5	per 100 sq. ft.

Diagrams 8-5 and 8-6 may be used for estimating furring and grounds, etc., using rate of work per 100 lin. ft. instead of 100 sq. ft.

16. Equipment.—The equipment used for rough carpenter work in light wood construction often consists of hand tools only, of which each carpenter should have a set. Sometimes workbenches, power bench saws, and portable electric saws may be used to advantage. If electric power is to be used, the

expense of providing for this power must not be omitted. See Art. 5 of this chapter for allowances for equipment.

Scaffolding will be usually required for most rough carpenter work. On large jobs, the scaffolding should be estimated as a separate item. The costs will include materials (less salvage), transportation, and labor of erection and removal. On small jobs, the scaffolding may be estimated at so much per square (100 sq. ft.) of wall surface. These costs may range from about $0.80 to $2.50 per square. When the same scaffolding may be used for other purposes, such as exterior finish, the cost per square for rough carpenter work will be reduced proportionately.

17. Estimates for Rough Carpenter Work.—Estimates for this kind of work are usually prepared by computing the materials, labor, equipment, overhead, and profit separately for all the rough carpenter work and then totaling. However, some estimators prefer to separate the rough carpenter work into framing, rough boarding, and miscellaneous, and then to estimate the materials, labor, equipment, and overhead separately for each of these three items. Such a method is satisfactory on the larger jobs. If unit estimates are desired, they are usually computed per 1,000 ft. b.m. of the lumber used, though in some instances they may be computed per 100 sq. ft. or square, or per wall panel (16 in. wide and about 8, 9, or 10 ft. high).

Overhead costs may range from 25 to 55 per cent of the labor costs, or from 15 to 35 per cent of the costs of materials and labor. Profit may vary from about 5 to 15 per cent of the sum of all other costs.

18. Illustrative Estimate.—Prepare an estimate of the total cost of the rough carpenter work (materials, labor, equipment, overhead, and profit) for a simple two-story residence.

Materials prices for materials delivered at the job are as follows:

Rough lumber for framing and sheathing, $48 per 1,000 ft. b.m.

Nails, $0.05 per pound. Insulating exterior sheathing board $75 per 1,000 sq. ft.,

Outside door frames $7. Inside door jamb sets $2. Window frames $4.

Labor wages are $2 per hour for carpenter, and $1.20 per hour for helper.

The materials take-off gave the following information:

Size of basement, 24 × 30. Basement wall in place.

Plate or sill on top of wall, 2 × 6.

Posts in basement, 8 × 8 by 7 ft. 0 in. high.

Built up girder, 8 × 12 by 29 ft. long.

First-floor joists, 2 × 12 by 12 ft. long, 16 in. on centers.
Second-floor joists, 2 × 10 by 12 ft. long, 16 in. on centers.
Second-floor ceiling beams, 2 × 8 by 12 ft. long, 16 in. on centers.
Rafters, 2 × 6 by 16 ft. long, 16 in. on centers.
Outside wall studs, 2 × 4 by 17 ft. 6 in. long, 16 in. on centers.
Attic wall joists at ends, 2 × 4 up to 9 ft. long, 16 in. on centers.
Basement partitions, 22 lin. ft. less 1 single door, 8 ft. high.
First-floor partitions:
  29 lin. ft. less 1 single door 32 in. wide and 1 opening 5 ft. 6 in. wide.
  23 lin. ft. less 2 single doors, each 32 in. wide.
  Height of partitions is 8 ft. 6 in.
Second-floor partitions:
  29 lin. ft., less 2 single doors, 32 in. wide.
  29 lin. ft., less 2 single doors, 32 in. wide.
  9 lin. ft., less 1 single door, 32 in. wide.
  9 lin. ft.
  9 lin. ft., less 1 single door, 28 in. wide.
  10 lin. ft., less 1 single door, 28 in. wide.
  10 lin. ft., less 1 single door, 28 in. wide.
  3 lin. ft.
  3 lin. ft.
  Partitions are 8 ft. high.
Outside doors, two, 36 in. wide, 6 ft. 9 in. high.
Attic doors are 6 ft. 9 in. high.
Windows, first floor, two double, 4 ft. 8 in. by 5 ft. 6 in.
  four single, 2 ft. 4 in. by 5 ft. 6 in.
  one single, 2 ft. 0 in. by 4 ft. 2 in.
Windows, second floor, two double, 4 ft. 8 in. by 5 ft. 2 in.
  five single, 2 ft. 4 in. by 5 ft. 2 in.
Windows, attic, two single, 2 ft. 0 in. by 3 ft. 10 in.

Materials: Framing:

	Ft. B.M.
Basement. 2 posts 8 × 8 by 7 ft. 0 in.	75
1 beam 8 × 12 by 29 ft. 0 in. (say 30 ft.)	240
1 sill plate 2 × 6 by 112 ft.	112
Joists. First-floor joists, each joist 2 × 12 by 12 ft. = 24 ft. b.m.	
Number of joists = (¾ × 30) × 2 = 23 × 2 = 46 plus 2 end joists and 2 partition joists = 50	1,200
Second-floor joists, each 2 × 10 by 12 ft. = 20 ft. b.m.	
Number of joists = (¾ × 30) × 2 = 23 × 2 = 46 plus 2 end joists and 4 partition joists = 52	1,040
Second-floor ceiling joists, each 2 × 8 by 12 ft. = 16 ft. b.m.	
Number of joists = (¾ × 30) × 2 = 23 × 2 = 46	736
Bridging 132 pairs of 1 × 3 by 18 in. long = 396 lin. ft.	100
Studs. Outside wall studs, each 2 × 4 by 17 ft. 6 in. (say 18 ft.) = 12 ft. b.m.	
¾(30 + 30 + 24 + 24) + 4 corners + 4 partition intersections + 18 (openings) = 108 at 12 ft. b.m.	1,296

Attic wall studs $\frac{3}{4}(24 + 24) + 2$ ends $= 38$	
Average height 4 ft. 6 in., or 3 ft. b.m.	114
Plates and caps $2(30 + 30 + 24 + 24) = 216$ lin. ft. of 2×4	144
Ribbons 108 ft. of 1×5, say	45
Fire stops at second floor, say 100 lin. ft. 2×4	67
Basement partition joists 2×4 by 8 ft. $= 5\frac{1}{3}$ ft. b.m.	
$\frac{3}{4}(22) + 1$ end $+ 2$ openings $= 20$	107
Plates and caps $2 \times 22 = 44$ lin. ft.	30
First-floor partitions, 2×4 by 8 ft. 6 in. $= 5\frac{2}{3}$ ft. b.m.	
$\frac{3}{4}(29) + 1$ end $+ 4$ openings $= 27$	
$\frac{3}{4}(23) + 1$ end $+ 4$ openings $= 23$	
Total of 50	284
Caps and plates $2(29 + 23) = 104$ lin. ft.	70
Second-floor partition, 2×4 by 8 ft. $= 5\frac{1}{3}$ ft. b.m.	
$\frac{3}{4}(29) + \frac{3}{4}(29) + \frac{3}{4}(9) + \frac{3}{4}(9) + \frac{3}{4}(10) + \frac{3}{4}(10)$	
$+ \frac{3}{4}(3) + \frac{3}{4}(3) + 9$ (ends) $+ 16$ (openings)	
$= 22 + 22 + 7 + 7 + 7 + 8 + 8 + 3 + 3 + 9 + 16 = 112$	598
Plates and caps $2(29 + 29 + 27 + 20 + 6)$	158
Rafters, $2(\frac{3}{4} \times 30) + 2$ ends $= 48$	
Each 2×6 by 16 ft. long $= 16$ ft. b.m.	768
Total framing net	7,174
Allow 5 per cent waste	358
Total	7,532
Say	7,500
Rough boarding:	
First floor, 1×8 laid diagonal	
Gross area, $24 \times 30 = 720$ sq. ft.	
Allow 20 per cent waste	865
Second floor, same	865
Attic floor, shiplap laid crosswise	
$24 \times 30 = 720$ sq. ft. Add 20 per cent for waste	865
Total rough flooring	2,595
Say	2,600
Exterior sheathing board for outside walls.	
$17.5(30 + 30 + 24 + 24) + 2\left(\frac{24 \times 9}{2}\right)$ (attic ends) $= 1{,}890 + 216 = 2{,}106$ sq. ft.	
Add about 5 per cent for waste, say	2,200
Note that as no deductions have been made for openings, no allowance for waste may be needed.	
Exterior sheathing board for roof, say $32 \times (2 \times 16) = 1{,}024$ sq. ft.	
Add 5 per cent for waste	1,100
Total sheathing board	3,300
Grounds, about 432 lin. ft. on first floor, plus about 600 lin. ft. on second floor for base, plus about 516 lin. ft. for molds gives 1,548 lin. ft. Allowing 5 per cent for waste gives a total of 1,625 lin. ft., or ft. b.m., say about	550

Door and window frames	
Door frames, outside	2
Inside	12
Window frames, double	4
Single	12
Nails, framing, say 10 lb. per 1,000 ft. b.m.	75 lb.
Rough boarding and grounds, say 20 lb. per 1,000 ft. b.m.	65 lb.
Exterior sheathing board, say 12 lb. per 1,000 sq. ft.	40 lb.
Total	180 lb.

Materials, summary:

				Cost
Framing,	7,500 ft. b.m.	at $72	=	$ 540
Rough boarding,	2,600 ft. b.m.	at $72	=	187
Sheathing board,	3,300 sq. ft.	at $75	=	247
Grounds,	550 ft. b.m.	at $72	=	40
Door frames,	2 at $7 and 12	at $ 2	=	38
Window frames,	4 at $8 and 12	at $ 4	=	80
Nails,	180 lb.	at $ 0.06	=	11
Total materials for framing			=	$1,143

Labor: Framing. This labor may be estimated per piece or per 1,000 ft. b.m.

Some estimators estimate per piece and check per 1,000 ft. b.m.

	Labor-hours
Basement, 2 posts, square cut and erect	= 3
1 beam, prepare and erect	= 8
1 sill plate	= 4
Joists, first floor, 50 pieces, 2 = 12 by 12 ft. at 0.50	= 25
Second floor, 52 pieces, 2 × 10 by 12 ft. at 0.50	= 26
Ceiling, 46 pieces, 2 × 8 by 12 ft. at 0.45	= 21
Bridging, 132 pieces, or 396 lin. ft.	6
Studs, outside wall, 108 pieces, 2 × 4 by 17 ft. 6 in. at 0.30	= 32
Attic wall, 38 pieces, 2 × 4 by 4 ft. 6 in. average at 0.25	= 10
Plates and caps, 2 × 4, 216 lin. ft.	= 6
Ribbons, 1 × 5, 108 lin. ft.	= 4
Fire stops, 2 × 4, 100 lin. ft.	= 4
Studs, partitions, basement. 20 pieces 2 × 4 by 8 ft. at 0.20	= 4
Caps and plates, 2 × 4, 44 lin. ft.	= 1
First floor, 50 pieces, 2 × 4 by 8 ft. 6 in. at 0.25	= 13
Caps and plates, 2 × 4, 104 lin. ft.	= 3
Second floor, 112 pieces, 2 × 4, by 8 ft. at 0.25	= 28
Plates and caps, 2 × 4, 111 lin. ft.	= 3
Rafters, 48 pieces, 2 × 6 by 16 ft. at 0.50	= 24
Total	= 225

Check by 1,000 ft. b.m. method.

When commenting on this estimate, it should be noted that different estimators would make different allowances for waste and would assume different rates of work depending upon their experience and judgment.

Some estimators would summarize the costs for framing, for rough boarding and sheathing, and for door and window frames separately and then obtain totals.

D. LIGHT WOOD CONSTRUCTION. FINISH WORK

19. Finish Work.—As stated previously, finish work may be divided into exterior and interior finish and these subdivided as desired. As indicated by the terms, exterior finish refers to the finish carpenter work required on the outside or exterior of the building, and interior finish to the finish carpenter work required on the inside or interior of the building. The following classification will give an idea of the items included.

Exterior finish:

- Siding and shingling on walls, including building paper.
- Trim, including molding, cornice, corner boards, water tables, etc.
- Doors, windows, blinds, and shutters.
- Roofing and flashing. Discussed in Chap. X.
- Steps and stoops.
- Porches, with various details listed such as floor and roof framing, sheathing, flooring, ceiling, roofing, columns, and various finish details.
- Exterior hardware.

Interior finish:

- Flooring, including deadening and sanding.
- Trim such as base, chair rail, plate rail, picture mold, beam casings, wainscot, panels.
- Stairs, stringers, treads and risers, balusters, rail, newels, coves.
- Windows and doors.
- Cabinet and mill work, including cupboards, ironing boards, cabinets, china closets, linen closets, medium cabinets, bookcases, columns, mantels, breakfast sets, drawers.
- Wooden ceiling.
- Miscellaneous, such as shelving and other items not previously listed.
- Interior hardware.

Some estimators consider all doors and windows as interior trim. However, in this chapter, door and window frames have been included with the framing, outside trim of doors and windows with exterior finish, outside doors and windows and inside trim with interior finish, and inside doors with interior finish. Some estimators place outside door and window trim with exterior finish, and the doors and windows and interior trim with interior finish.

20. **Materials.**—There are several units of measurement for the materials used for finish work. Table 8-14 gives many of the materials and the units by which they are estimated.

TABLE 8-14.—UNITS OF MEASUREMENT FOR MATERIALS FOR FINISH WORK

Exterior finish	Unit	Interior finish	Unit
Siding	1,000 ft. b.m., 100 sq. ft.	Flooring	1,000 ft. b.m., 100 sq. ft.
Shingles, (siding)	100 sq. ft., bundles, 1,000 pieces	Deadening felt	100 sq. ft., roll
Building paper	Roll, 100 sq. ft.	Trim, base, chair rail, base rail, moldings, etc.	100 lin. ft.
Doors and windows	Piece	Panels	100 sq. ft.
Trim	Side, or set	Ceiling	1,000 ft. b.m., 100 sq. ft.
Blinds and shutters	Piece, or pair	Windows and doors	Piece
Trim, various	100 lin. ft.	Trim	Side, or set
Porches, framing	1,000 ft. b.m.		
Boarding, sheathing	1,000 ft. b.m.	Cabinet and mill work, various items	Piece
Flooring, ceiling, roofing	100 sq. ft.	Miscellaneous	Various
Trim	100 lin. ft.	Interior hardware	Piece, or pair, dozen, set pound, etc.
Posts	Piece		
Hardware	Piece, or pair, dozen, set, pound, etc.	Nails and bolts	Pound
Nails and bolts	Pound		

Much of the molding is measured and priced by the "molding inch," which is the equivalent of a piece of lumber 1 in. square and 1 ft. long. The cross-sectional area is figured on the full size of stock from which the molding is made. For example,

a $\frac{3}{4}$- by $1\frac{3}{4}$-in. molding would be made from 1- by 2-in. material, and a strip 1 ft. long would contain 2 molding inches. Prices are often quoted per 100 lin. ft. per molding inch, and vary with different kinds of woods and moldings. Waste in moldings will be end waste and may vary from 5 to 10 per cent.

Wood siding may be drop or novelty siding, or lap or bevel siding. Table 8-15 gives approximate materials required.

TABLE 8-15.—AMOUNT OF SIDING PER 100 SQ. FT. OF WALL SURFACE

Width and type	Exposure, inches	Lap and waste, per cent	Ft. b.m. per 100 sq. ft.	Nails, lb. per 100 sq. ft.
6-in. lap or bevel........	4.75	25	125	2–3
6-in. lap or bevel........	4.50	33	133	2–3
5-in. lap or bevel........	3.75	40	140	2–3
5-in. lap or bevel........	3.50	50	150	2–3
4-in. lap or bevel........	2.75	50	150	3–4
4-in. lap or bevel........	2.50	60	160	3–4
6-in. drop..............	5.00	25	125	3–4

Diagram 8-9 may be used for estimating cost of siding.

Shingle siding is composed of special wooden, asbestos, or asphalt shingles. These shingles are usually larger than ordinary shingles, and come packed in bundles or cartons. The number in a bundle or carton is sufficient to cover an area of 25, $33\frac{1}{3}$, or 50 sq. ft. with the exposure or head lap specified. Head or end lap may vary from about 2 to 4 in. and exposure from 4 or 5 in. up to 12 in., according to the dimensions of the shingle siding used.

Wood siding shingles are usually about 24 in. long and 0.50 in. thick at the butts. With a 10-in. exposure, three bundles are required per square. Cost per square may vary from $7 to $20 (or $2.50 to $7 per bundle). These shingles may be laid on wood sheathing, or over old siding. Building paper should be placed under them. Nails required will be 3 to 5 lb. per square. The amount of waste for ordinary walls will vary from 3 to 10 per cent.

Asphalt siding shingles come in various sizes and weights and may be in either single or strip form. The head lap may vary from 1.5 to 3 in. and exposure from 4 to 10 in. Shingles are

packed in bundles or cartons. Usually two, three, or four bundles are required per square. Cost per square may vary from $4 to $15. Weight of asphalt siding when laid may vary from about 80 to 300 lb. per square. Asphalt diamond point and imitation brick siding, in strips four tabs or four bricks long, come in bundles covering about 50 or 33⅓ sq. ft., respectively. Prices per square may range from $3 to $10. Special corner strips are required for all corners. A box of 100 corner strips may cost about $3 or $4. Waste may range from 3 to 10 per cent for ordinary walls. Asphalt shingles are usually laid over a covering of building paper. From 3 to 5 lb. of large-headed galvanized roofing nails 1 to 1.75 in. long are required per square. These nails cost $0.07 to $0.10 per pound.

Asbestos siding shingles are usually about 24 in. long and 12 or 16 in. wide. They should be laid over a good building paper or a light- or medium-weight roofing felt (15 to 30 lb. per square). The roofing felt comes in rolls of 108, 216, or 432 sq. ft. covering 1, 2, or 4 squares with a 2-in. lap. From 0.50 to 1.25 lb. of nails are required per square for the roofing felt and from 3 to 4 lb. of large-headed galvanized roofing nails per square for the shingles. Sometimes special bronze nails are used. Cost of asbestos siding shingles per square may vary from $6 to $15 per square.

Ceiling materials vary a little in thickness and width. Ordinary ceiling is about ⅝ in. thick, 3½ in. wide, and is matched and beaded. The waste is about 25 per cent, and 20 to 25 lb. of nails is required per 1,000 ft. b.m., or 2 to 3 lb. per square of 100 sq. ft.

For most trim, such as is measured per 100 lin. ft., 5 to 10 per cent should be allowed for waste. From 2 to 3 lb. of nails per 100 lin. ft. will usually be sufficient.

The materials for flooring are usually estimated per 1,000 ft. b.m., or per 100 sq. ft. with allowance for waste. Finish flooring is usually about $^{13}\!/\!_{16}$ in. thick and of various widths from 1.5 to 3.5 in. or more.

Board feet required for 100 sq. ft. of floor area for flooring $1^{1}\!/\!_{16}$ in. thick is based on the assumption that this thickness is considered as 1 in. when measuring board feet. If considered as 1.5 or 2 in., then values given must be multiplied by 1.5 or 2, respectively.

Diagram 8-9 may be used for estimating cost of finish flooring.

TABLE 8-16.—AMOUNT OF FINISH FLOORING PER 100 SQ. FT. OF FLOOR SURFACE

Flooring		Waste, per cent	Ft. b.m. per 100 sq. ft. floor area	Nails per 100 sq. ft. floor area
Width, in.	Thickness, in.			
1.5	3/8	40	140	4– 7
1.5	13/16	40	140	6– 8
2.25	13/16	35	135	5– 7
3.25	13/16	30	130	5– 7
4.25	13/16	25	125	4– 6
5.25	13/16	20	120	4– 6
2.25	1 1/16	35	135	6– 8
3.25	1 1/16	30	130	6– 8
4.25	1 1/16	25	125	7–10
5.25	1 1/16	20	120	7–10

Take-off.—Perhaps the simplest and best method of taking off materials and labor for finish work is to list the items under headings and subheadings such as

Exterior finish. Siding, shingling, trim, doors, windows, porches (framing, flooring, posts, ceiling, roofing, trim, rail, etc.), miscellaneous, etc.

Interior finish:

Basement. Doors, windows, stairs, shelves, ceiling, etc.
First floor. Flooring, trim, ceiling, paneling, doors, windows, stairs, cabinetwork (mantels, cabinets, cupboards, etc.), hardware, etc.
Second floor and other floors. Same as for first floor.

A good reminder list suitable for the type of structure considered should be checked so as to avoid omissions. See Appendix A for a typical reminder list. The plans and specifications must be scrutinized carefully so that no details are omitted.

Whenever possible, "stock" sizes of materials should be used to save time and expense of making "specials."

Dimensions, style, kind, catalogue number, quality, and other specifications should be noted.

For example, doors should be described as to kind of wood, style, width, length, thickness, panels, etc. Window sash should be described as to size, number of lights, kind of glass, etc. Door and window frames should have style, quality, and dimensions stated. Door and window trim should be described as to wood, dimension, style, etc. Stairs should be described in detail as to treads, risers, balusters, rails, newels, etc. Cabinetwork should be described in detail with sketches. Interior and exterior trim should be described according to wood, style, size, etc.

If desired, interior finish may be given in considerable detail. For example, an exterior door with frame and trim may be divided into side jambs, head jamb, side casings, head casing, sill, drip cap, inside casing, buck band, plinth, door, lock, hinges, etc. However, such detail is rarely necessary unless the door, for example, is to be fabricated almost entirely on the job. Usually a listing such as exterior door complete will be satisfactory, or the listing may be divided into three or four items as frame, exterior trim and interior trim, door, and hardware.

For preliminary and approximate estimates, the various items may be priced from catalogues. For exact estimates, all items should be listed and prices obtained from the mill or dealer. No attempt will be made here to give approximate prices for all the various items of finished woodwork.

21. **Labor.**—The labor required for finish work will vary considerably according to skill, ability, and inclination of carpenter, working conditions, kind of wood (hard or soft), etc. Finish work with a hard wood may require 20 to 35 per cent more time than like work with a soft wood. Consequently, the values given in the Tables 8-17 and 8-18 are approximate, and should be varied according to the conditions of the particular job. Diagrams 8-5, 8-6, 8-7, and 8-8 may be used for estimating labor costs of finish carpenter work.

Many estimators consider a door, a window, or a flight of stairs as one unit, and estimate labor required for a complete unit. Others go into more detail. For example, they may divide the labor for a door into frame, trim, hanging, and hardware, and for a flight of stairs into stringers, treads and risers, nosings, coves, newels, railings, balusters, etc. Such detail is usually not necessary except for special work.

22. Equipment.—The equipment required for finish work will invariably include a fairly complete set of hand tools for each carpenter and may include a few sawhorses and benches, a small portable electric saw, and electric sander. The costs will usually be the transportation charges for the carpenters' kits and other equipment, plus a small charge for horses and bench, and necessary charges for portable electric saws and electric sanders, as the case may be. The costs of providing the power (lines, switches, meters) should be included.

TABLE 8-17.—APPROXIMATE LABOR REQUIRED FOR EXTERIOR FINISH

Item	Unit	Labor-hours	Item	Unit	Labor-hours
Ceiling, matched	1,000 ft. b.m.	25–40	Door, exterior, single	Complete	5– 8
	100 sq. ft.	3– 5	Frame	One	1– 2
Siding, lap, narrow (lap or bevel).	1,000 ft. b.m.	20–50	Trim	Set	1– 2
	100 sq. ft.	3– 8	Hanging door	One	1– 2
Lap, wide (lap or bevel).	1,000 ft. b.m.	15–45	Hardware	Set	1– 2
	100 sq. ft.	2– 6	Door, exterior, double	Complete	7–12
Drop	1,000 ft. b.m.	12–40	Frame	One	2– 3
	100 sq. ft.	2– 5	Trim	Set	1– 3
			Hanging	Pair	2– 3
Shingles (siding) on walls.	100 sq. ft.	3– 8	Hardware	Set	2– 3
Building paper on walls	100 sq. ft.	1– 2	Window, single	Complete	4– 7
Cornice	100 lin. ft.	4–20	Frame	One	1– 2
String course	100 lin. ft.	4– 8	Trim	Set	1– 2
Mold	100 lin. ft.	4– 8	Hanging	2 sash	1– 2
Water table	100 lin. ft.	3– 6	Hardware	Set	1– 2
Corner board	100 lin. ft.	3– 5	Window, double	Complete	5– 9
Blinds and shutters	Pair	1– 4	Frame	One	1– 2
Porches:*			Trim	Set	1– 2
Columns	Each	1– 2	Hanging	4 sash	2– 3
Rail complete	100 lin. ft.	40–70	Hardware	Set	1– 3
Steps, set of 4	Set	8–16	Window, triple	Complete	8–12
			Frame	One	2– 3
			Trim	Set	1– 3
			Handling	6 sash	3– 4
			Hardware	Set	2– 3
			Screens, doors	Each	3– 5
			Windows	Each	1

* For other porch details, see tables on framing, flooring, roofing, etc.

Exterior finish work will usually require the use of some scaffolds and ladders. Frequently, the same scaffolds that were erected for the rough carpenter work may be left in place and used for the finish work. Then the cost of scaffolds will be part of the lumber cost plus the labor of removal. An allowance of $0.35 to $0.75 per 100 sq. ft. of wall surface is usually sufficient.

However, if separate scaffolding must be provided for exterior finish, the costs will be greater and may range from about $0.80 to $2.50 per 100 sq. ft. of wall surface. Scaffolding should be estimated separately and in detail for large jobs.

TABLE 8-18.—APPROXIMATE LABOR REQUIRED FOR INTERIOR FINISH

Item	Unit	Labor-hours	Item	Unit	Labor-hours
Wood ceiling	1,000 ft. b.m.	25–40	Door, single	Complete	3– 6
	100 sq. ft.	3– 5	Frame	One	1
Paneling and plywood	100 sq. ft.	3–15	Trim	Set	1– 2
Plaster board	1,000 ft. b.m.	10–20	Hanging	One	1
	100 sq. ft.	1– 3	Hardware	Set	1
Floors, finished hardwood, matched narrow.	1,000 ft. b.m.	25–40	Door, double	Complete	4– 8
	100 sq. ft.	4– 6	Frame	One	1– 2
			Trim	Set	1– 3
Wide, 3¼ in. and over.	1,000 ft. b.m.	20–35	Hanging	Two	1– 2
	100 sq. ft.	3– 5	Hardware	Set	1– 2
Floors, finished, softwood, matched.	1,000 ft. b.m.	16–30	Opening, framed	Complete	2– 4
	100 sq. ft.	2– 4	Frame	One	1– 2
			Trim	Set	1– 2
Building paper between floors	100 sq. ft.	1– 2	Stairs, cellar, complete.	10 ft. or one story	4– 8
Deadening felt	100 sq. ft.	1– 3			
Sanding floors, hand	100 sq. ft.	2– 4	Stairs, back, or enclosed.	12 ft. or one story	8– 20
With sander	100 sq. ft.	1– 2			
Wainscot	100 sq. ft.	3– 5	Stairs, front, open	12 ft. or one story	20– 60
Baseboard	100 lin. ft.	4– 7			
Chair rail	100 lin. ft.	4– 6	Stairs, front, open, and ornate.	12 ft. or one story	40–100
Plate rail	100 lin. ft.	4–10			
Picture mold	100 lin. ft.	2– 6	Mantels	One	3– 10
Mold, various	100 lin. ft.	1– 6	Installing ready-made medium cabinets, closets, ironing boards, broom closets, cupboards, china closets, bookcases, linen closets, etc.	One small	1– 4
Beam casings	100 lin. ft.	4– 8		One medium	2– 6
				One large	3– 8

23. Estimates for Finish Work.—Estimates for finish work may be prepared by considering all finish items together and estimating the materials, labor, and equipment. Or the estimates may be prepared by considering the items separately and estimating costs of materials, labor, and equipment for each item and then totaling. Either way is satisfactory, provided that no costs are omitted.

Some estimators divide the carpenter work into rough work and finish work without subdividing the finish work into exterior

and interior finish. This procedure is frequently followed on small jobs.

Note that costs of door and window frames were included in the previous estimate for rough carpenter work. Frequently, the rough carpenter sets all door and window frames, the finish carpenter installs outside doors and windows and outside trim with other exterior finish, and the finish carpenter does not install the inside trim until after the lathing and plastering has been completed. The cost of door and window frames were included in the estimate for the rough work, and the costs of doors and windows, less frames, will be included with the finish work.

Overhead costs may vary from about 25 to 55 per cent of the labor costs, or from 15 to 35 per cent of the costs of both material and labor. Profit may range from about 5 to 15 per cent of all other costs.

24. Illustrative Estimate.—Prepare an approximate estimate for the finish work for the simple two-story residence for which an estimate for the rough carpenter work was prepared in Art. 18 of this chapter. Assume that local carpenters' wages are $1.50 per hour and that no helpers or apprentices will be used. The take-off gave the following information. The prices given were quoted by a local dealer.

Exterior finish. Bevel or lap siding, 6 in. wide, 4.5-in. exposure. Total area 2,106 sq. ft.
  No deductions for openings.
  Building paper, area 2,106 sq. ft. Price $2 per roll.
  One front door, special, complete with trim and hardware less frame. Price $26.
  One rear door, complete with trim and hardware. Price $17.
  Four double windows, complete with trim and hardware, less frame. Price, $14 each.
  Twelve single windows, complete with trim and hardware, less frame. Price, $9.50 each.
  Screens, 2 doors, 4 double windows, 12 single windows.
  Cornice on ends, allow 70 lin. ft.
  Cornice on sides, allow 70 lin. ft.
  Water table, 108 lin. ft.

Interior finish:
  Basement. Basement stairs.
    One door with trim and hardware, less frame.
  First floor. Four inside doors, with trim and hardware, less frame.
    Building paper between rough and finish flooring, area 700 sq. ft.
    Flooring, hardwood $^{13}\!/_{16}$ by $2\frac{1}{4}$ plain, first grade, area 700 sq. ft.
    Base, base mold, and quarter round, length 220 ft.
    Picture mold (crown and picture), length 220 ft.

Mantel, living room.
China closet, dining room.
Kitchen, ironing-board closet.
Broom closet.
Two cupboards or dressers.
Stairs, open, first to second floor.
One coat closet.
Second floor. Eight inside doors with trim and hardware, less frame.
Deadening felt between rough and finish floors, area 700 sq. ft.
Flooring, hardwood. $^{13}/_{16}$ by $2\frac{1}{4}$ plain, first grade, area 700 sq. ft.
Base, base mold, and quarter round, length 300 ft.
Picture mold, single, length 300 ft.
Bath room, medicine cabinet, and towel cabinet.
Linen closet, complete with door, drawers, and shelves.
Three clothes closets, poles and shelves.
Stairs, second floor to attic, enclosed.

The finish materials and labor may be estimated and tabulated as follows. Nails are included with material estimates. Labor required for cabinetwork, doors, windows, and screens is for fitting and installing.

MATERIAL AND LABOR ESTIMATES

Item and description	Material cost	Labor-hours	Labor cost
Siding:			
Building paper, 2,100 sq. ft. at $2 per roll of 216 sq. ft.	$ 20	25	$ 38
Bevel siding 6 in., 4.5 in. exposed, 2,100 sq. ft. at $90 per 1,000 ft. b.m. Allow 33 % for lap and waste, plus nails	255	105	57
Other exterior trim:			
Cornice on sides, 70 lin. ft. at $36 per 100, 10 % waste	30	6	9
Cornice on ends, 70 lin. ft. at $26 per 100, 10 % waste	21	6	9
Water table, 108 lin. ft. at $19 per 100, 10 % waste	16	6	9
Doors and windows with trim and hardware, less frame:			
Outside doors, front	26	5	7
Rear	17	5	7
Inside doors, basement (1)	6	3	5
First floor (4)	36	20	30
Second floor (8)	64	34	51
Double windows (4)	48	30	45
Single windows (12)	92	60	90
Subtotal, carried forward	$631	305	$457

CHAPTER IX

STRUCTURAL STEEL

1. Estimating of Structural Steel.—The correct estimating of structural steel is a comparatively complex and detailed problem. The form and manner in which the estimate is made will depend on the work that is to be done by the estimator's company. For example, fabricating estimates will vary considerably in detail from construction or erection estimates. As this text is intended more for the use of the general contractor, this chapter will consider only the work done by the general constructor or builder, *i.e.*, by assuming that the contractor buys the steel already fabricated and erects the steel with his own construction gang. However, in some instances, the providing of the steel, the fabrication, and also the erection is sublet to a steel company that specializes in this type of work. On other jobs, the general contractor may purchase the steel ready fabricated and sublet the erection to another company. The estimate should be divided into the five general headings of material, labor, equipment, overhead, and profit.

The materials estimate should include all quantities required and all costs of the materials delivered either at the job or at the nearest and most convenient railway siding or dock. The cost of material delivered at the job is recommended, even if the contractor provides the handling and trucking between railway siding and job. The materials costs may include:

Mill costs, including base prices and various extras.

Transportation costs from mill to fabrication shops.

Fabrication costs, including shop drawings and details, handling, fabrication, painting, inspection, and overhead. For some jobs, the fabrication costs may equal the mill costs of the materials.

Transportation costs from fabrication shop to most convenient railway siding or dock.

Transportation costs from railway siding or dock to job, including handling from railway car to truck, trucking to job, and

unloading from truck. Some estimators prefer to include these costs with the erection costs, especially if the general contractor furnishes the labor, trucks, and handling equipment.

The labor estimate should include all labor costs of erecting the steel at the site. Items included may be labor required for:

Hoisting the steel in place and temporarily fastening with bolts. (The labor required for erecting, operating, moving or resetting, and taking down of hoists and derricks is usually included here.)

Plumbing the structure.

Riveting, welding, or bolting as specified.

Painting after erection.

The equipment estimate should include all equipment costs such as rentals, depreciation, maintenance and repairs, power and fuel, and transportation to and from the job. If not included with the labor estimate, the labor for erection, moving or resetting, takedown, and operation should be included also.

The overhead expenses may be based on labor alone, on the sum of material and labor costs, or part may be based on labor and part on materials if the overhead costs may be readily divided between these two items. On structural-steel jobs, the overhead expenses are high and may vary considerably. Compensation insurance, inspection and general supervision, and preparation of drawings (if needed) are important items. Overhead expenses may range from 40 to 100 per cent of the labor costs.

The profit is based on the sum of all other costs and may range from 5 to 25 per cent, depending upon the hazards and uncertainties related to the particular job, the competition expected, what the contractor thinks is fair, and also what the contractor thinks he can get.

2. The Take-off or List of Materials.—When preparing a list of materials, the plans and specifications should be studied so that the estimator will have a general understanding of the requirements of the job. Then the take-off is carefully prepared, all the materials being listed in a logical order or sequence. This order may vary with different types of structures and with different estimators. Usually it is not necessary to make an erection estimate as detailed as a fabrication estimate. All main items should be listed separately, but smaller items such as beam fastenings, bolts, rivets, and minor details may be approxi-

Roof covering. Corrugated steel or other roofing.
Skylights including sash and glazing.
Ventilators.
Miscellaneous.
Steel frame office (multistoried) buildings. These are usually estimated by the floor.
Basement. Column bases and caps.
Columns and details.
Girders and beams and details.
Metal lumber, if included in contract.
Bracing, if any.
Steel flooring, if any.
Miscellaneous.
First and other floors.
Columns and column details.
Girders and beams and details.
Lintels.
Metal lumber.
Bracing.
Miscellaneous.
Roof. Columns and column details.
Girders and beams and details.
Purlins.
Metal lumber.
Bracing.
Roof covering, if of steel.
Miscellaneous.
Exterior finish. All items of steel such as cornice and cove.
Steel sash and glazing.
Siding.
Miscellaneous.
Large girders. Each girder estimated in same manner as for a bridge girder.
Building trusses. Each truss estimated in same manner as for a bridge truss.

Some estimators when estimating steel-frame buildings prefer to take off the material in the following order:

Columns including main items, plates, caps, and connections.
Floor beams and girders including details.
Bracing, such as wind bracing.
Girders, as for a bridge girder.
Trusses, as for a bridge truss.
Metal lumber, joists, and studs.
Roofing materials.
Steel sash and glazing.
Miscellaneous items.

After completing the take-off in a manner similar to that described, many estimators group all the materials for convenience in pricing somewhat as follows:

Structural shapes. Grouped according to shape (I beams, H beams, channels, angles, T's, Z's) with subdivisions according to standard or special sizes and subgroups according to large, medium, and small sizes or weight. The grouping into large, medium, and small sizes will vary with the different estimators. For example, I beams 6 in. or less in depth may be called small, those 6 to 15 in. called medium, and those over 15 in. in depth called large. The "base" size or weight may be called the median size.

Bars and rods. According to size and shape.

Flats. According to size and thickness.

Plates. According to size and thickness, specials being noted.

Connections. According to kind, etc.

Rivets, bolts, small details, etc., often as a percentage of the weights of other materials.

Corrugated steel. Finish, gage, and length noted.

Steel sash. Details noted.

Miscellaneous items.

For an illustration of a take-off, see the illustrative estimate at the end of this chapter.

3. Materials. *Structural Steel.*—After the take-off has been completed, the unit weights of the various items should be noted opposite the corresponding items. Then the total weights of each of the items should be computed. Sometimes the weight computations are made at the same time the materials are listed. Structural-steel handbooks should be consulted for dimensions and unit weights of structural-steel shapes and of other steel materials. The total estimated weight, as computed by the estimator, should agree within 3 per cent of the actual shipping weight of the fabricated steel. Hence, it is advisable for the estimator to slightly overestimate the weights in the take-off so as to allow for small overruns and omissions.

As structural steel is priced per 100 lb. (or pounds or ton), the weights of the various items must be found. These weights should be based on

Rectangular dimensions for all plates.

Over-all lengths of all structural shapes.

No allowances for clipping, milling, punching, or boring.

Allowances for overrun calculated according to the percentage of overrun permitted by the A.S.T.M. standards.

Shop rivets may be estimated as follows:

Diameter, Inches	Weight per 100 Rivets, Pounds
½	20
⅝	30
¾	50
⅞	100
1	125

Field rivets should be estimated at actual weights, with 10 per cent allowed for waste. About 20 to 30 field rivets will be needed for each ton of steel, and more may be required in special cases.

Field bolts should be estimated at actual weights, with 5 per cent allowed for waste. For temporary bolting, about 3 to 10 bolts will be required for each ton of steel.

Paint will increase the weight of structural steel about 8 or 10 lb. per ton per coat.

Details may be approximately estimated as follows:

TABLE 9-1.—APPROXIMATE WEIGHTS OF DETAILS

Shape	Rivets, per cent	Details, per cent
Columns	3–4	10–15
Beams	1–2	5–20
Built-up girders	5–6	10–12
Roof trusses	3–4	15–20

Beam details vary considerably. The weights of standard connections may be found in structural-steel handbooks. Some estimators allow about 4 per cent of the weights of all members for rivets, and about 20 per cent of the weights of main members for details.

The weight of steel for the steel frame only of a mill building, one story high (15 to 25 ft. to bottom chord of truss), with no crane runways, may vary from about 10 to 15 lb. of steel per square foot of floor area. If crane runways are provided, the weight of steel frame may vary from about 12 to 20 lb. of steel per square foot of floor area. The weight of crane runways will

depend upon the size or capacity of the crane and the crane span. The weight of crane runway may vary from about 150 lb. per lineal foot for a 10-ton crane with a 40-ft. span to about 400 lb. per lineal foot for a 30-ton crane with an 80-ft. span. Note that 2 lin. ft. of crane runways are required for each lineal foot of crane travel. Weights of steel frames for buildings several stories high may vary from about 2 to 4 lb. per cubic foot of building.

Structural steel is usually priced and sold by the hundredweight (100 lb.). The price quoted is usually that f.o.b. the mill. In addition to the base price per 100 lb., there are several extras which may be added. The base price usually applies to certain standard sizes. Extras are charged for such things as the following:

Sizes and sections other than standard. The extras may vary from $0.05 to $0.30 per 100 lb.

Quantity extras for shipments less than 6,000 lb. These extras may range from $0.25 to $1.25 per 100 lb. for smaller shipments.

Length extras for pieces less than 8 ft. or greater than 80 ft. These extras may vary from $0.10 to $1.55 per 100 lb.

Special cutting and milling extras, usually about $0.10 per 100 lb.

Cambering extras. About $2 per net ton, with a minimum of $2.50 per piece.

Quality, specification, and testing extras. A.S.T.M. Standard for Carbon Structural Steels is base. Extras for other specifications and standards may range from $0.10 to $3 per 100 lb. Physical-test extras are usually $0.10 per 100 lb. Chemical-test extras may range from nothing to $0.25 or so per 100 lb.

The reader is referred to up-to-date price lists of the steel companies for correct charges for extras.

The extras may increase the price so that the price paid (including extras) may range from base price to base plus 8 to 30 per cent.

Overrun or overweight caused by permissible variations in dimensions and weight may increase the costs up to about 5 per cent.

For general estimates on structural steel, the total weight may be computed and the mill price for each kind of material taken at about base plus 10 per cent.

Whenever possible, the material list (or plans and specifications) should be referred to the mill and the correct mill prices obtained.

Fabrication costs will vary according to the amount of shopwork done on the steel. These costs are usually quoted per ton and vary considerably. Shop painting (one coat) is usually estimated at $1 per ton. General handling charge is about $1 per ton. Inspection may cost $1 to $2 per ton. Overhead in a shop may vary from 50 to 100 per cent of all labor costs. The cost of making drawings, detailing, and checking may range from $1 to $6 per ton, $2 to $4 being the average. Approximate fabrication costs, including handling, drawings, fabricating, and overhead are given in Table 9-2.

TABLE 9-2.—APPROXIMATE COSTS OF STEEL FABRICATION

Description	Cost per ton	Cost per 100 lb.
Foundations, anchor bolts, gritlage beams	$12–$20	$0.60–$1.00
Steel columns and struts, I and H sections	12– 16	0.60– 0.80
Built-up sections	25– 40	1.25– 2.00
Beams, I, H, and channels, punched and framed	6– 10	0.30– 0.50
Plate riveted on flange	12– 20	0.60– 1.00
Built-up girders	20– 40	1.00– 2.00
Riveted trusses	25– 50	1.25– 0.50
Miscellaneous framing, angle braces, and girts	6– 15	0.30– 0.75
Skylight and dormer frames	30– 60	1.50– 3.00
Floor plates	10– 15	0.50– 0.75
Knee braces	30– 40	1.50– 2.00

These costs will vary considerably according to the job requirements and labor wages. Hence, the estimator should secure the fabricator's figures whenever possible.

Transportation costs from mill to fabricator and to a convenient railway siding and dock will depend upon the freight rates in force between the places considered. These rates will vary according to classification and also from time to time. The estimator should consult with transportation agents and the mill or fabricator so as to obtain the best freight classification and rate. Carload lots should be shipped whenever practical.

In summing up, the cost of structural steel f.o.b. at convenient siding may be roughly as follows:

Item	Cost per 100 Lb.
Base plus extras	About \$2.00–\$3.50
Fabrication	About 1.00– 2.50
Freight	About 0.25– 1.00
Giving a total	About \$3.50 to \$7

Corrugated Steel.—Corrugated sheet steel may be used for exterior surfaces as siding and roofing. This material is available in regular open-hearth or rust-resisting (copper alloy) steels and in black (unpainted mill), painted, and galvanized finishes. Standard widths are 26 in. for siding and 27.5 in. for roofing. Corrugations are usually $2\frac{2}{3}$ or 3 in. in width. The 26-in. width siding sheet has both edges turned the same way, giving a net width of 24 in. when lapped 2 in. or about one corrugation. The 27.5-in. width roofing sheet has one edge turned up and the other down, giving a net width of 24 in. when lapped 3.5 in. or about 1.5 corrugations. Standard lengths are 5 to 12 ft., with 1-ft. variations. End lap for roofing sheets should be 6 or 8 in. and for siding sheets 4 or 6 in. Sheet-steel flashing should be provided at roof ridges, eaves, windows, and wherever necessary to ensure watertight results.

The approximate gross area of sheets may be found as follows:

Roofing (27.5-in.) sheets = net area + end laps + 15 per cent for 3.5-in. side laps
Siding (26-in.) width = net area + end laps + 10 per cent for 2-in. side laps

Roughly, an allowance of about 15 per cent is required for end and side laps for siding and about 22 per cent for roofing.

Table 9-3 gives the gage, gage thickness, weights per square foot, and maximum span between supports for corrugated siding and roofing having $2\frac{2}{3}$- or 3-in. corrugations.

The 27.5-in. material weighs about 1.25 per cent more per square foot of surface covered than the 26-in. width.

Painted black sheets weigh about 0.015 lb. per square foot more than the unpainted black sheets.

Table 9-4 gives approximate weights of corrugated steel required per square, based on an allowance of 15 per cent for the 26-in. siding and 22 per cent for the 27.5-in. roofing.

The painted black sheets will weigh about 1.5 to 2 lb. more per square than the unpainted black sheets.

Approximate prices at the present time (1946) for corrugated roofing material per 100 lb. delivered at the job are $4 to $6 for

TABLE 9-3.—GAGE, THICKNESS, WEIGHTS, AND MAXIMUM SPANS OF CORRUGATED-STEEL SIDING AND ROOFING, WITH 2⅔- OR 3-IN. CORRUGATIONS

U. S. gage	Thick-ness, in.	26-in. siding sheets, lb. per sq. ft.		27.5-in. roofing sheets, lb. per sq. ft.		Maximum span between supports	
		Galva-nized	Black	Galva-nized	Black	Siding	Roofing
						Ft. In.	Ft. In.
16	0.061	2.86	2.69	2.90	2.73	5 10	5 9
18	0.049	2.32	2.15	2.35	2.18	5 10	5 9
20	0.037	1.78	1.65	1.81	1.64	5 10	5 9
22	0.031	1.51	1.35	1.53	1.36	5 10	4 9
24	0.024	1.25	1.08	1.26	1.09	4 10	3 9
26	0.018	0.98	0.81	0.99	0.82	3 10	2 9
27	0.0165	0.91	0.74	0.92	0.75	3 10	2 9
28	0.015	0.84	0.67	0.85	0.68	3 10	2 9
29	0.0135	0.77	....	0.78	....	3 10	2 6

TABLE 9-4.—APPROXIMATE WEIGHTS OF CORRUGATED-STEEL SIDING AND ROOFING REQUIRED PER SQUARE

U.S. gage	26-in. siding		27.5-in. roofing	
	Galvanized	Black	Galvanized	Black
16	339	310	354	333
18	267	248	287	266
20	205	187	221	200
22	174	155	187	166
24	144	124	154	133
26	113	93	121	100
27	105	85	112	92
28	97	77	104	83
29	89	...	95	

black (mill) finish and about $5 to $7 for galvanized. Base prices per 100 lb. at the mill are about $3 for black finish and $3.50 for

framing details. Small trusses and built-up frames will average from 350 to 450 sq. ft. per ton. Suitable paint may cost $1.50 to $3.50 per gallon. See Chap. XV on Painting, Papering, and Glazing for information on painting structural steel.

4. **Labor.**—The labor required on a structural-steel job will depend upon the wages and skill of the workers, upon the ability of the foreman, and upon the labor-saving equipment used, as well as upon the kind of job, exactness of fabrication of the materials, weather, and working conditions.

The labor for erecting structural-steel framing may include two or more of the following:

1. Labor of handling steel at railway siding and at site.
2. Labor of erecting, moving, and taking down of hoists and derricks.
3. Labor of erection, including plumbing and temporary bolting.
4. Labor of riveting, bolting, or welding.
5. Labor of painting.
6. Labor of installing corrugated siding and roofing, metal sash, and miscellaneous items.

The labor for unloading railway cars or trucks may be organized into gangs of two, three, or four men as convenient.

Steel erection is usually done by a gang of skilled men working under a foreman. A convenient steel-erection gang may consist of 1 foreman, 1 derrick or hoist operator, 1 signal man, 1 boom man, 2 ground men for loading derrick, and 2 sky men for connecting up (bolting).

Riveting and welding may be done by one or more small gangs of about four men each.

Painting may be done by a gang of painters starting at the top of the structure and working down. One or more ground men or helpers may be needed to assist the painters.

Corrugated siding and roofing, steel sash, and miscellaneous items may be installed by men working in one or more small gangs of two to four men each. If the material must be hoisted or raised more than about two stories, extra men and equipment may be needed.

Steel lumber is not usually installed by structural-steel workers and may be installed by other metalworkers or carpenters.

Steel sash is usually not installed by the structural-steel gang but may be installed by other steelworkers, such as a special crew provided by the sash manufacturer or dealer.

Ornamental steel of various kinds is usually not installed by the structural-steel gang, but may be installed by other steel and iron workers, tinsmiths, or special workers provided by the manufacturers or dealers.

At the railroad siding, the material may be unloaded on the ground and then on trucks or it may be unloaded directly from the cars to the trucks. Small pieces may be handled by men without a hoist or derrick. Medium-weight pieces may be handled by a gin pole, shear legs, or a hand or power derrick. A derrick may be required for the heavier pieces. Sometimes the railroad company has a derrick available, but usually the contractor has to supply it. A small movable crane mounted on caterpillar treads and powered by a gasoline engine is a good piece of equipment for this type of work. After the material is trucked to the site, it is unloaded by hand, pole derrick (hand operated), or by power crane or derrick as the case may be. A small movable gasoline crane is suitable here also.

The contractor must estimate the sizes and weights of the structural members in advance and have suitable gangs and equipment to handle it. Columns usually come fabricated in two-story lengths (20 to 30 ft. long). Built-up beams and girders are entirely assembled before shipping. Light trusses of short spans may be entirely assembled. Longer trusses may be assembled in two or three parts so that their erection may be simplified on the job. Heavy trusses often have to be almost entirely assembled on the job.

Before preparing approximate estimates of the labor required for erection in labor-hours per ton of steel, the general method or plan of erection for the particular structure should be considered, as well as the various sizes and weights of the various structural members and the equipment to be used.

If the structure is a mill building of a story in height with roof trusses, it may be erected with the aid of a gin pole or a small gasoline crawler crane. The columns are erected first and plumbed and braced. The trusses are assembled on the ground and then raised in position and secured. Trusses may be shipped

in one, two, or three pieces according to size. After the trusses are in place, the purlins and horizontal bracing are installed. After all parts of the structure are plumbed and bolted, the required riveting or welding may be done. Painting comes next. After painting, the corrugated siding and roofing, steel sash, skylights, ventilators, etc., may be installed, glazing done, and other painting done as required.

TABLE 9-5.—APPROXIMATE LABOR-HOURS REQUIRED FOR EQUIPMENT

Kind of Work	Labor-hours
Gin pole, large, unload and erect	40– 60
Move horizontally	20– 35
Take down and load	12– 25
Gin pole, small, unload and erect	20– 40
Move horizontally	10– 20
Take down and load	8– 15
Guy derrick, large, unload and erect	50–110
Move horizontally	15– 30
Move vertically (2 floors)	20– 50
Take down and load	20– 60
Stiffleg derrick, large (25-ton), unload and erect	180–320
Take down and load	100–170
Stiffleg derrick, medium (10-ton), unload and erect	80–150
Take down and load	40– 70
Derrick, small (5-ton), unload and erect	20– 40
Take down and load	10– 20
Breast derrick, small, unload and erect	8– 12
Move horizontally	2– 4
Move vertically (2 floors)	3– 5
Take down and load	3– 5
Air compressor, large, steam power, install	30– 50
Remove	30– 50
Air compressor, medium, electric or gas or oil, install	10– 20
Remove	10– 20
Air compressor, small portable, electric or gas power,	
Install	2– 5
Remove	2– 5

If the structure is several stories high, as an office building, the columns are erected and plumbed, and then the beams and girders are bolted in place. As the columns are usually two stories in length, the framing for two stories is erected and then the derrick or hoist is placed on the last floor and the framing for the next two stories erected. This process is repeated until the framing is completed. The derrick frame should be long

enough so that the derrick moves will be kept at a minimum. After the frame has been erected, it is plumbed by means of cross bracing of wire rope with turnbuckles and additional bolts provided to hold the frame in place. Some erectors are careful to keep the frame plumb as it is erected so that but little final plumbing is required. Other erectors plumb the frame every

TABLE 9-6.—APPROXIMATE LABOR-HOURS REQUIRED FOR HANDLING AND ERECTING STRUCTURAL STEEL

Kind of Work	Labor-hours per Ton of Steel
Handling, such as unloading from railway car to truck and from truck to ground, with aid of derrick or crane when needed	1– 2
(average)	(1.3–1.5)
Erection labor:	
Foundation work	5– 8
Columns and struts	6–10
Beams and channels, ordinary	4– 8
Beams and channels, special	6–12
Plate girders	6–12
Crane rails	6–12
Knee braces	10–16
Floor plates	8–12
Fittings, bolts, rods, anchor plates	4– 6
Girts, angles, angle braces, purlins	6–11
Skylight frames and curbs	10–16
Monitor frames	10–18
Dormers	10–16
Door frames	12–20
Riveted trusses	8–16
Transmission towers	25–40
Light steel trestles	16–30
Steel framing, as for power or heating plant	14–22
Steel mill building (with roof trusses, roofing, and siding)	7–15
Steel-frame multistoried building (as office buildings)	6–12

few stories, so that riveting or welding may be started before the entire frame is erected. Special equipment and extra men may be required for erecting extra-heavy or large pieces like girders or trusses. After erection, all connections are riveted, bolted, or welded as the case may be. The steel frame is usually painted after the riveting or welding is completed, the painters working from the top down. The derrick may be removed after the frame is erected, after the riveting is completed, or after paint-

TABLE 9-7.—APPROXIMATE LABOR-HOURS REQUIRED FOR BOLTING, RIVETING, AND OTHER WORK

Kind of Work	Labor-hours	
Temporary bolting (3 to 10 bolts per ton of steel)	5 – 7	per 100 bolts
Riveting, air driven (20 to 40 rivets per ton of steel):		
On ground, easy work	6 –10	per 100 rivets
Trusses	7 –12	per 100 rivets
Steel office buildings	10 –15	per 100 rivets
Steel mill buildings	10 –13	per 100 rivets
Light trestles and towers	14 –20	per 100 rivets
Riveting, hand driven:		
Easy work	12 –16	per 100 rivets
Difficult work	16 –25	per 100 rivets
Painting structural steel, one coat:		
Heavy-weight members	0.5 – 0.9	per ton
Medium-weight members	0.7 – 1.4	per ton
Light-weight members	1.0 – 2.0	per ton
Corrugated-steel siding and roofing, on wood:		
26 U.S. gage and lighter	0.5 – 1.5	per square
Heavier than 26 gage	1.0 – 2.0	per square
Corrugated-steel siding and roofing on metal frame:		
26 U.S. gage and lighter	1.0 – 3.0	per square
Heavier than 26 gage	1.5 – 4.0	per square
Asbestos covered	3.0 – 6.0	per square
Anticondensation lining for corrugated roofing	2 – 4	per square
Steel roofing trim, ridge, valley, cornice, etc.	2 – 6	per 100 lin. ft.
Steel lumber:		
Joists, 4 to 8 in depth	0.15– 0.30	per each
	15 –25	per 100 lin. ft.
Joists, 8 to 12 in depth	0.25– 0.50	per each
	20 –40	per 100 lin. ft.
Studs, light, 1 lb. per foot or less	0.6– 0.15	per each
	8 –16	per 100 lin. ft.
Studs, heavy, 2 or more pounds per foot	0.12– 0.25	per each
	12 –20	per 100 lin. ft.
Furring, and grounds	3 – 6	per 100 lin. ft
Steel sash, installing only	3 –12	per 100 sq. ft. of opening area
Painting or calking	2 – 5	per 100 lin. ft. of joints
Installing and calking	5 –16	per 100 sq. ft.

ing. Sometimes it is advisable to leave the derrick in place after erection for hoisting other materials, but it is usually removed after the framing is completed.

The trusses for small truss bridges may come assembled or may be assembled on the ground and then raised in position by a crane or derrick. Then the cross bracing, portals, and floor system are installed and riveted or otherwise secured in place. Painting follows.

The trusses for medium-size truss bridges may be assembled on the ground and then raised in position by one or two derricks; they may be partly assembled on the ground, the parts raised in position, and then bolted; or the trusses may be assembled in position by means of false work and small derricks and cranes. After the trusses are erected, the floor system, bracing, portals, etc., are installed. Painting follows.

Large trussed bridges may be erected piece by piece on falsework by the aid of traveling or movable cranes or derricks; or they may be erected by the cantilever method, the frame being designed to support its own weight and that of the derrick, as erection progresses. The main bracing is usually erected with the trusses. Floor systems and other details are placed later.

The approximate amounts of labor required for various items of work connected with the erection of structural-steel work are given in Tables 9-5, 9-6, and 9-7. As there are many variables that may affect the labor-hours required, the tabular values are to be considered as approximate only. It is assumed that the laborers are skilled in their work and are organized in suitable gangs under the direction of competent foremen.

Equipment labor will vary with type of power units (boiler and steam engine, gas or oil engine, electric motor, etc.).

The following diagrams may be used for estimating labor costs: Diagrams 9-1 and 9-2 (pages 605 and 606) for equipment; Diagrams 9-3, 9-4, 9-5, and 9-6 (pages 607, 608, 609, and 610) for handling, erecting, riveting, and painting structural steel; and Diagram 9-7 (page 611) for applying corrugated steel.

5. Equipment.—The equipment used on a structural-steel job will vary with the kind of structure, size of job, and the equipment the contractor has available and thinks is suitable for the particular work. The equipment may include:

For unloading and transporting steel from railway siding to site:

- One or two gin poles, derricks or cranes, either hand or power operated.
- Dollies and other small tools.
- Autotrucks and auto trailers.
- Special trucks and trailers may be needed for extra large or heavy pieces.

For erection of steel:

- Derrick or crane, preferably power operated. May be of any kind (gin pole, guy, stiffleg, breast, or tractor type) and capacity suitable for the job.
- Power unit for derrick, steam engine and boiler, electric motor, or gasoline or oil engine.
- Fuel and oil for power unit (coal, water, gasoline, oil, electricity).
- Winches.
- Blocks.
- Wire and manila rope.
- Bolts, turnbuckles, drift pins, and various small tools.
- Small portable building for office and tool house.

For riveting:

- Rivets.
- Riveting tools, air hammers, etc.
- Air piping and hose.
- Hand lines and hand hoist.
- Forge and tools.
- Scaffolds.
- Air compressor with power unit (steam, gasoline, or electric).
- Fuel for forges and for compressor operation.

For welding:

- Welding metal.
- Welding machines.
- Welding tools.
- Scaffolds.
- Hand lines and hand hoists.
- Gas for welding.
- Electricity for welding.

For painting:

Paint.
Brushes, pails, and other painters' tools.
Ladders, rope slings, small scaffolds, boatswain's chairs.
Hand lines.

Approximately 1 ton of coal or 200 gal. of fuel oil or gasoline will be required for erecting 30 to 50 tons of steel.

About 1 ton of coal or 200 gal. of fuel oil or gasoline will be required for the compressor for every 400 to 600 field rivets.

The various types of cranes and derricks that may be used for structural-steel work include:

Locomotive cranes on tracks, 40- to 105-ft. boom.
Tractor or crawler cranes, 20- to 50-ft. booms.
Stiffleg derricks, varying length of booms and capacities.
Guy derricks, guyed at top of mast.
Breast derricks.
Jinniwink, A frame, one stiffleg, and boom.
Gin pole, single pole guyed at top.
A frame, guyed at top.
Hoists and block and tackle.

The cranes and derricks of the larger capacities are invariably power operated. The ones of smaller capacities (say 5 tons or less) may be either hand or power operated. Each type has its own advantages and disadvantages in construction use.

On many jobs, an estimate of the cost of equipment per ton of steel is satisfactory. On other jobs, the estimator may need to estimate the costs of each large or important piece of equipment separately. To find the equipment costs per ton of steel, the total cost of all equipment used on the job is first estimated and then this total cost is divided by the number of tons of steel in the job.

For approximate estimates of the cost of equipment used in structural-steel work, the following values may be used. It is thought that these ranges of values will be fairly representative of the equipment costs per ton for most of the ordinary structural-steel jobs. The lower values may be expected on simple and easy jobs where the tonnage is large and the individual prices are easy to handle. The higher values may be expected on the

more difficult jobs, when the tonnage is small, and when the individual prices are not easy to handle.

TABLE 9-8.—APPROXIMATE EQUIPMENT COSTS PER TON OF STRUCTURAL STEEL

Handling and transporting from railway siding to site
  Each crane or derrick, hand operated
  = $0.10 to $0.20 per ton of steel handled
  Power operated = $0.15 to $0.30 per ton of steel handled
  (Power-operated cranes and derricks are faster and usually save labor costs)
  Transportation in autotrucks, per ton of steel hauled
  = $1.50 + $0.15 × miles hauled
  (*i.e.*, the truck cost is $1.50 per ton for time of loading and unloading plus $0.15 for each ton mile)
  Or for the average job = $1.65 to $3.00 per ton of steel handled
Erection:
  Crane or derrick including power
  = $2.00 to $10.00 per ton of steel
  All other tools and equipment = $0.30 to $1.00 per ton of steel
Riveting:
  Compressor, $6 to $10 per 100 field rivets, or
  $1.00 to $2.00 per ton of steel
  Other tools, $1 to $4 per 100 field rivets, or
  $0.30 to $1.10 per ton of steel
Welding:
  Electric welders = $1.00 to $2.00 per ton of steel
  Other tools = $0.20 to $1.00 per ton of steel
Painting of steel frame = $0.20 to $0.70 per ton of steel
Corrugated steel, erection of = $0.10 to $0.40 per square

For more detailed estimates of equipment costs, the cost for the job of each important or large piece of equipment is found separately. Tools and minor equipment may be considered together and the cost for the job estimated. The cost of equipment should include costs of transportation to and from the job, rentals, depreciation, repairs, maintenance, fuel, oil, etc., as the case may be. The labor costs of erection, operation, moving, and taking down are usually included with the labor estimate. When not included in the labor estimate, these costs must be included with the equipment costs.

Further information is given in Chap. XVII on Construction Plant and Equipment and in Appendices *B*, *C*, and *D*. The "Contractors' Equipment Ownership Expense" prepared and

published by The Associated General Contractors of America, Inc., Munsey Building, Washington, D. C., contains about the best information on owner's equipment costs. Other worthwhile information may be found in schedules prepared and distributed by different government agencies and by various manufacturers. Information in regard to equipment costs is sometimes published in engineering periodicals. Examples are the Depreciation Schedule, Construction Equipment Rental Rates, and Index of Construction Machinery Prices published in the Engineering News-Record, Apr. 18, 1946.

6. Overhead and Profit.—Overhead costs on structural-steel work will be comparatively large because of the hazards and uncertainties of the work, the more office work and supervision required, and the higher rates charged for compensation and other insurance. The overhead costs are usually based on labor. The percentage of the labor costs may range from 20 to 35 per cent plus insurance for compensation, social security, etc.

Compensation insurance rates vary considerably in different states: At the present time (1946), compensation insurance base rates for structural-steel and -iron erection vary from 5 to 35 per cent, with an average of about 15 to 20 per cent. The estimator should consult the insurance companies so that he will have correct information covering compensation insurance. Social security and other taxes vary in different states and may range from 2 to 5 per cent. These compensation insurance costs and taxes are usually treated as overhead items, though some estimators consider them as direct labor costs and include them with the labor. For further information see Appendix *E*.

Sometimes the overhead costs are estimated separately for materials, labor, and equipment, using different rates for each item. These rates are determined by the past experiences and the cost records of the company plus the judgment of the estimator. These rates may be based on materials costs or quantities (per ton, on labor wages or hours, and on equipment costs or time. For example, overhead costs may range from 5 to 15 per cent of the materials costs, 25 to 50 per cent of the labor costs, including compensation insurance taxes, and 4 to 10 per cent of the equipment costs.

Total overhead may range from about 45 to 70 per cent of all labor costs on an average with possible extreme ranges of 40 to 100 per cent.

The percentage of profit figured on structural-steel work is usually comparatively high and may range from 10 to 25 per cent of the sum of all other costs, or from 15 to 30 per cent of the sum of labor, equipment, and overhead costs. Sometimes the percentages allowed for profit vary with the items, being lower for materials and higher for labor costs.

7. Structural-steel Estimates.—Structural-steel estimates will include the following:

Materials. Cost at nearest railway siding or cost at job.

Labor. All labor costs involved.

Equipment. Costs of all equipment required for the particular job.

Overhead. Usually based on labor costs.

Profit. Based on sum of all other costs.

Total costs. Sum of all other costs.

Unit costs per ton or per hundredweight may also be computed.

Estimates may be summarized and tabulated to show unit costs per ton or per hundredweight of steel as well as total costs.

Some estimators subdivide their estimates as follows:

Materials. Cost f.o.b. nearest siding.

Handling and transportation. From railway siding to job site.

  Labor. Costs of all labor used for this purpose.

  Equipment. Costs of all equipment used.

Erecting, riveting, or welding, and painting.

  Labor. Costs of labor for erection and riveting, etc.

  Equipment. Costs of erection and riveting equipment.

Overhead. If not subdivided and included with other costs.

Profit.

This form of estimate has the advantage of giving the estimated costs of the materials f.o.b. siding, the costs of moving the steel from siding to job site, and the costs of erecting, riveting or welding, and painting the steel. A few estimators go into further detail, and figure costs of erecting, riveting or welding, and painting separately, as different gangs are used for these three kinds of work.

Materials Take-off

One-story Steel Mill Building 60 by 105 ft. Job No.________

No. of pieces	Size, etc.	Length, each, ft.	Weight per ft.- lb.	H's, I's, [s, lb.	∠s, lb.	Plates, lb.	Rivets, lb.	Total
22	Wall columns, 14 × 8H	20.0	43.0	18,920				
	Details, 15%					2,840		
	Rivets, 4%						760	22,520
22	Wall beams, 10 × 4H.	15.0	17.0	5,610				
	Details, 10%					560		
	Rivets, 3%						170	6,340
	Wall bracing:							
8	∠s 2 × 2 × ¼	25.0	3.2		640			
16	∠s 2 × 2 × ¼	12.5	3.2		640			
	Details, 10%					130		
	Rivets, 3%						40	1,450
120	Wall girts [s, 6 in.	15.0	8.2	14,760				
	Rivets, 4%						590	15,350
	One truss:							
4	∠s 5 × 3½ × ⅜	35.0	10.4		1,455			
4	∠s 3 × 3 × ¼	19.0	4.9		375			
2	∠s 3 × 3 × ¼	23.0	4.9		225			
4	∠s 3 × 2½ × ¼	19.0	4.5		340			
4	∠s 3 × 2½ × ¼	9.0	4.5		160			
4	∠s 3 × 2½ × ¼	8.0	4.5		145			
4	∠s 2 × 2 × ¼	9.5	3.2		120			
4	∠s 2½ × 2 × ¼	4.0	3.6		60			
1	∠ 2 × 2 × ¼	15.0	3.2		50			
	Total				2,930			
	Details, 20%					585		
	Rivets, 4%						120	(3,635)
(8)	Trusses				23,440	4,680	960	29,080
(16)	Knee braces:							
32	∠s 3½ × 3 × ⅜	11.0	7.9		2,745			
	Rivets, 4%						110	2,855
	Roof purlins:							
182	I's 6 in.	15.0	12.50	34,125				
	Details 10%					3,415		
	Rivets, 3%						1,025	38,565
	Upper chord bracing:							
16	∠s 2 × 2 × ¼	22.0	3.2		1,130			
	Details, 10%					115		
	Rivets, 3%						35	1,280
	Lower chord bracing:							
4	∠s 4 × 3 × 5/16	25.0	7.2		720			
8	∠s 4 × 3 × 5/16	20.0	7.2		1,155			
20	∠s 4 × 3 × 5/16	15.0	7.2		2,160			
4	∠s 2 × 2 × ¼	27.0	3.2		345			
8	∠s 2 × 2 × ¼	25.0	3.2		640			
	Total				5,020			
	Details, 10%					500		
	Rivets, 3%						150	5,670
	Summary:							
	Trusses				23,440	4,680	960	29,080
	All other			73,415	10,175	7,560	2,880	94,030
	Total			73,415	33,615	12,240	3,840	123,110

8. Illustrative Estimate.—*Prepare a cost estimate for the structural-steel frame for a small steel mill building 60 by 105 ft. in size, 20 ft. from ground level to bottom of roof trusses. The building has seven 15-ft. bays, thus requiring eight trusses of 60-ft. span. Diagonal cross bracing is provided in the second and sixth bays for walls and for the roof trusses in planes of both the upper and lower chords. Truck haul from railway siding to site is 2 miles.*

The following prices are assumed to apply:

Structural steel, mill prices	$2.60 per 100 lb.
Fabrication, including drawings, shop labor and 1 coat paint	
Roof trusses	35.00 per ton
Other work	12.00 per ton
Freight	0.28 per 100 lb.
Wages of structural-steel workers	1.85 per hour
Wage of foreman	2.40 per hour
Wage of power-crane or derrick operator	1.85 per hour
Painters	1.65 per hour

Equipment costs to be assumed by estimator
Overhead costs, 8 per cent of material costs
32 per cent of labor costs
5 per cent of equipment costs
Profit, 11 per cent of all other costs

Materials (see Materials Take-off, page 283):

Mill price, 123,110 lb. at $2.60 per 100		= $3,200	
Fabrication, roof trusses, 29,080 lb. at $35 per ton	= $510		
Other steel, 94,030 lb. at $12 per ton	= $565	1,075	
Freight, 123,110 lb. at $0.28 per 100 lb.		= 345	
Total cost of steel, f.o.b. railway siding		= $4,620	
Cost per ton = $75. Cost per 100 lb. = $3.75			
Miscellaneous materials. Sometimes these materials are included with the equipment costs.			
Field rivets, 1,540, about 800 lb. at $4 per 100 lb.	= $32		
Field bolts 250, at $0.07 each	= 18		
Paint, about 41 gal. for 1 coat at $1.90 per gal.	= 78		
		$128	
Total materials cost			= $4,748

Labor. Assume gang of 1 foreman and 6 men.
Total hourly cost = $2.40 + (1.85 × 6) = $13.50
Cost per labor-hour = $2.25
Handling at railway siding and at site.
Assume hand cranes available at each place.

Assume 1.4 labor-hours per ton for trusses and 1.2 labor-hours per ton for other steel, at siding and at site.

Other steel, 94,030 lb. at (1.2 + 1.2) hr. per ton = 113 hr.

Trusses, 29,080 lb. at (1.4 + 1.4) hr. per ton = 41 hr.

Total labor-hours = 154

Labor cost, 154 hr. at \$2.25 = \$ 347

Erection of steel (and plumbing) with crawler gasoline-powered crane.

Assume 8 labor-hours per ton for other steel and 11 labor-hours per ton for the roof trusses.

Other steel, 94,030 lb. at 8 hr. per ton = 376 hr.

Trusses, 29,080 lb. at 11 hr. per ton = 160 hr.

Total (average = 10.33 hr. per ton for frame) = 536 hr.

Labor cost, 536 hr. at \$2.25 = \$1,206

Equipment labor. As a crawler crane is used for the erection and hand cranes at siding and site for handling steel, the extra labor required for erecting, moving, and taking down equipment should be quite low. By assuming a portable gas-powered air compressor, the labor required for moving this unit will be low. Probably 40 hr. of extra labor for equipment will be sufficient.

Labor cost, 40 hr. at \$2.25 = \$ 90

Riveting. Assuming 25 field rivets per ton, number of field rivets will be 1,540. By assuming 12 hr. per 100 rivets, labor-hours will be 185 for riveting.

Labor cost, 185 hr. at \$2.25 = \$ 417

Painting. Painting this frame will not be difficult. About 1.2 hr. per ton should be a reasonable allowance.

Hours required = 74

Labor cost, 74 hr. at \$1.65 = \$ 122

Total labor cost = \$2,182

Equipment. The following equipment and costs for the job are assumed:

Hand crane at railway siding = \$ 7

Hand crane at site, including transportation = 20

Trucks for transporting steel

For haul of 2 miles, cost per ton is \$1.80,

123,110 lb. at \$1.80 per ton = 110

Crawler gasoline crane for erection, including fuel and all other costs, estimated at \$30 for trans-

2. Roofing Materials. The materials used in roofing and flashing may be classified as to kind of material (wood, asphalt, composition, metal, canvas, etc.) or as to type of material (shingles, rolls, tile, strips, pieces, etc.).

In the absence of other information, the weights per square of various roofing materials may be taken from Table 10-1.

TABLE 10-1. APPROXIMATE WEIGHTS PER SQUARE OF VARIOUS ROOFING MATERIALS

Roofing Material	Weight per Square, Pounds
Sheathing, wood	225–350
Felt, per layer	15–30
Tar or asphalt, per coat	20–30
Tar and slag roof, 4-ply	400
Asphalt roll roofing	55–75
Canvas roofing	15–25
Copper, No. 22 B and S gage	125
Corrugated galvanized steel 22 U. S. gage	175
Corrugated galvanized steel 24 U. S. gage	145
Corrugated galvanized steel 26 U. S. gage	115
Corrugated galvanized steel 28 U. S. gage	100
Lead, ⅛ in. thick	750
Glass, ⅛ in. thick	175
Shingles, asbestos	200
Shingles, asphalt	150–400
Shingles, wood	200
Shingles, slate	450–700
Tile, clay and cement	800–1,200

3. Roofing Paper and Felt. Roofing paper usually comes in rolls of varying lengths and weights. A roll may contain 108, 216, or 432 sq. ft. or enough for one, two, or four squares with a 2-in. lap. Weights of roofing paper may vary from 4 or 5 lb. up to 30 lb. or so per square. Prices may range from about \$0.20 to \$1 per square. Roofing paper is often fastened with large-headed tacks about $\frac{9}{16}$ in. long and costing \$0.10 to \$0.15 per half-pound package (enough for one square).

Roofing felt usually comes in rolls of varying areas and of weights from about 15 to 40 lb. per square. The felt may be priced per roll with area and weight given, or per 100 lb. with weight per square given. Cost per square may vary from \$0.50 to \$1.50, and cost per 100 lb. from \$2 to \$4. The felt is impregnated with tar or asphalt, with the asphalt usually being con-

sidered as a better material and costing a little more. About 0.50 lb. of ⅝-in. to 1.25 lb. of 1-in. large-head galvanized nails may be required per square when the felt is nailed to a wood surface.

Diagrams 10-1 and 10-3 (pages 612 and 614) may be used for estimating the costs per square of paper and felt.

4. **Wood Shingles.**—Wood shingles usually come in random widths (say from 4 to 12 in.) packed in bundles. Each bundle contains the equivalent of 250 four-inch shingles. The length of the shingles is usually 16 or 18 in. In general, the length should equal three exposures plus 1.5 to 3 in. in addition for head or end lap so as to provide a roof covering three layers thick. The thickness of the shingles at the butt is usually 0.40 (five make 2 in.) or 0.45 in. (five make 2.25 in.). The exposure is usually 4, 4.5, 5, 5.5, or 6 in. Some manufacturers pack their shingles in special bundles or cartons, each carton containing enough shingles to cover 25, 33⅓, or 50 sq. ft. or so, with a stated exposure of 5 or 5.5 in. The wood used is usually red cedar of No. 1 or No. 2 grade. Prices of shingles may range from about $2 to $6 per standard bundle of 250 shingles, or from $8 to $25 per square.

Table 10-2.—Wooden Shingles and Nails Required per Square of 100 Sq. Ft.

Length, inches	Exposure, inches	Number of shingles	Nails, pounds
16	4	900	4.0
	4.5	800	3.6
	5	720	3.3
18	5.5	655	3.0
	6	600	2.8
24	8	450	2.3
	10	360	2.0

Wood shingles are usually nailed to the shingle strips or wood roof sheathing with two nails per shingle. Usually no building paper is placed between the roof shingles and the roof sheathing, though building paper is frequently placed between siding

shingles and the wall sheathing. The number of nails required per square may vary from 3 to 5 lb., depending upon the exposure and consequent number of shingles, or about 4 lb. of 4-penny shingle nails per 1,000 shingles. Nails may cost $0.03 to $0.06 per lb. for plain-wire nails and $0.05 to $0.10 per lb. for galvanized-wire nails.

The amount of waste with wood shingles may vary from about 8 to 25 per cent, depending on how much the roof is cut up by ridges, valleys, dormers, etc. A double row of shingles is usually laid along all eaves.

Diagrams 10-1, 10-2 (page 613), and 10-5 (page 616) may be used for estimating the costs per square for wooden shingles.

Table 10-2 gives theoretical quantities of wood shingles and nails required per 100 sq. ft. of roof area with no waste.

5. Asphalt Shingles.—Asphalt shingles are usually packed in bundles or cartons. Each bundle may contain enough shingles for 25, 33⅓, or 50 sq. ft. of roof. Exposures are usually 4, 4.5, or 5 in. Single shingles vary from about 12 in. in length for 4-in. exposure to 16 in. in length for 5-in. exposure. Strip shingles are usually 36 by 10, 11, or 12 in. in size, and each strip is usually cut or marked to indicate three or four shingles, *i.e.*, three or four tabs. Asphalt shingles are usually laid over a covering of building or sheathing paper.

Asphalt shingles are made in varying weights and finishes. Weights per bundle may vary from 40 to 125 lb. Weights per square when laid may vary from about 150 to 400 lb. Prices may range from about $4 to $12 per square, or from $1.25 to $4 per bundle.

Waste in laying asphalt shingles may vary from about 4 up to 15 per cent, depending on how much the roof is cut up by ridges, valleys, dormers, etc.

Asphalt starting strips and ridge and valley strips come in rolls 9 and 18 in. wide by 36 ft. long, weighing about 22 and 44 lb. per roll, and costing about $0.50 and $1 per roll, respectively.

Large-headed galvanized roofing nails, 1 to 1.75 in. long, are used with asphalt shingles. These nails cost $0.05 to $0.10 per pound. From 4 to 5 lb. per square are required for individual 9- by 12-in. shingles, from 2.5 to 4.0 lb. per square for individual 12- by 16-in. shingles, and from 2.5 to 4.0 lb. per square for three- and four-tab strip shingles.

Diagrams 10-1 and 10-2 may be used for estimating the costs per square for asphalt shingles.

6. Asbestos Shingles.—Asbestos shingles are available in a number of sizes and styles. Hexagonal shingles about 16 by 16 in. or square styles about 8 by 16 in., 9.5 by 22 in., and 12 by 24 in. are common. These shingles come in bundles containing enough shingles for 25, 33⅓, or 50 sq. ft. of surface. The lap is about 2 in., so the exposure is equal to one-half (length minus end lap). The cost per square may range from about \$6 to \$15. The average weight is about 200 lb. per square. The waste may vary from about 8 to 25 per cent. From 3 to 4 lb. of 1.5- or 1.75-in. galvanized roofing nails are needed per square.

Asbestos shingles are usually laid over a layer of roofing felt, which may weigh 15 to 35 lb. per square.

Diagrams 10-2 and 10-5 may be used for estimating the cost per square of asbestos shingles.

7. Slate Shingles.—Slate shingles are usually rectangular in shape, and vary in width from 6 to 16 in. and in length from 12 to 24 in. The end lap is usually about 3 in., and the exposure is one-half (length − end lap). These shingles are often priced per square of 100 sq. ft. (lap and other dimensions given). The price per square may range from \$8 to \$100. The thickness of the individual shingle may vary from about 0.20 to 2.00 in. Average weight of slate shingles is about 500 to 600 lb. per square.

Waste may vary from 5 to 25 per cent. depending on the form and irregularities of the roof.

Slate shingles are laid over a layer of roofing felt, as are asbestos shingles.

From 2 to 6 lb. of nails may be required per square, depending on size and thickness of shingle. Copper nails are recommended. From 3 to 4 lb. is usually enough per square. These nails may cost \$0.25 to \$0.50 per pound.

Diagrams 10-2 and 10-5 may be used for estimating the cost per square for slate shingles.

8. Metal Shingles.—Stamped metal shingles of copper, tin (steel with tin surfaces), galvanized steel, etc., are available in many shapes and sizes. Quantities required per square will depend upon size, overlap, and exposure. The shingles are often quoted per square and sometimes per 100. Prices vary

considerably, the cost per square ranging from about \$6 per square and up.

Metal flashing shingles are usually about 5 by 7 in. in size and are made of comparatively light weight tinned or galvanized steel material of about No. 28 or 29 gage. They may cost about \$1 to \$2 for a bundle of 100. Copper flashing shingles are also used, and may cost from four to six times as much as the galvanized-steel shingles, depending on size of shingle and gage.

Diagrams 10-2 and 10-5 may be used for estimating the costs per square of metal shingles.

9. Tile.—Cement tile, clay tile, and steel tile (imitation of clay tile) are available in many sizes and shapes. These tile may cost \$10 to \$200 per square, depending upon material and style. Hips and valleys may cost \$0.25 to \$1 per lineal foot.

The tile are usually laid over a layer of roofing felt weighing about 30 to 40 lb. per square. Furring strips and lath are required with some styles.

As most tile are furnished and laid by the manufacturer or dealers, the estimator should give the plans and specifications to them so as to secure their estimates.

10. Asphalt-roll Roofing.—Asphalt-roll roofing usually comes in rolls 32 or 36 in. wide and of a length sufficient to cover 100 sq. ft. of surface with an allowance for 2-in. laps. The actual area per roll is usually about 108 sq. ft. Sometimes a 3-in. lap is provided for. The finish may be a mica or slate surface. The weights per roll or per square may vary from 35 to 110 lb. per square by 5-lb. intervals. The 65- to 90-lb. weights are common. The price per square (or per roll) may vary from about \$1.10 to \$4, depending upon weight, finish, and style.

Nails and roofing cement for laps may or may not be included with the rolls. From 2 to 4 lb. of 1- to 1.75-in. galvanized large-headed nails are required per square or roll. Roofing cement is needed at the laps and around flashings. This costs about \$0.03 to \$0.15 per pound, depending on composition, color, and quantity. From 2 to 5 lb. should be enough per square.

Asphalt-roll roofing is usually laid on wood roof sheathing or over old roofs. Building or sheathing paper is rarely used under asphalt-roll roofing.

Diagram 10-1 may be used for estimating the cost per square of asphalt-roll roofing.

11. Composition or Built-up Roofing.—Composition or built-up roofing may consist of two to five plys of roofing felt or similar material with alternate layers or coats of tar or asphalt and sometimes a surfacing of gravel or slag. The roofing felt used may vary from 15 to 40 lb. per ply per square, the tar or asphalt from about 20 to 30 lb. per coat per square, gravel surfacing from 350 to 450 lb. per square, and slag surfacing from 250 to 350 lb. per square.

Roofing felt usually comes in rolls of various weights, each roll containing 108 sq. ft. or enough material for one square with 2-in. laps. Roofing felt may be priced per roll or per 100 lb. as previously stated in the article on Roofing Paper and Felt.

Tar pitch usually comes in 350-lb. barrels and may cost $20 to $40 per ton. Asphalt is usually priced per gallon (1 gal. weighing about 9.5 lb.) and may cost $0.25 to $0.75 per gallon or $2.50 to $8 per 100 lb.

Slag and gravel suitable for roofing may cost $2 to $4 per ton.

A little roofing cement may be needed for patching and also for flashings.

The composition roofing is used on comparatively flat surfaces only. If the surface is of concrete, the concrete is first given a priming coat of asphalt or tar roof paint, or a coat of the regular tar or asphalt thinned a little, before the first layer of felt is placed. Hence, on a concrete roof, there will be one more coating of tar or asphalt than there are plys of felt. The same is true for metal surfaces when a composition roof is placed over an old metal roof. For wooden surfaces, a layer of felt is placed first, and this layer may or may not be counted as one ply. Sometimes the composition roofing is extended for 6 in. to 1 ft. up the sides of brick or other walls to serve as flashing.

The materials estimate should note:

Squares. Number of squares, including any extras as for flashing.

Felt. Number of plys and weight per ply per square. Tar or asphalt impregnated.

Tar or asphalt. Number of coats and pounds per coat per square.

Slag or gravel. Pounds per square.

Miscellaneous materials. Such as nails, roofing cement, asphalt priming paint, and roofing paper per square.

In addition to the types of composition roofing mentioned, there are many special types prepared and applied by various manufacturers and dealers.

Diagrams 10-1 and 10-3 may be used for estimating the costs per square of composition roofing materials.

12. Canvas Roofing.—Canvas roofing of two- or three-ply construction may come in rolls 29 to 72 in. in width, and 100 yd. in length. The weight may vary from about 12 to 24 oz. per square yard. The canvas roofing should be laid in paint on a smooth surface and the finished roof given one or two coats of paint. The canvas should be fastened by copper or galvanized-steel or iron tacks about 5/8 to 3/4 in. long and spaced about 1 in. or less apart. From 8 to 12 per cent should be allowed for laps and waste in cutting and fitting. Flashings may be formed by extending the canvas 6 to 8 in. up the sides of the walls. This extra material must be allowed for. The canvas may cost \$30 to \$80 per square, according to weight and number of plys. The cost of the paint is additional.

The materials estimate for a canvas roof should include canvas, tacks, and paint.

13. Metal Roofing.—Metal roofing is usually rolled open-hearth steel roofing of about 22 to 29 U. S. gage and may be plain (black), painted, tinned, or galvanized. Rust-resisting steel alloys (usually copper bearing) are also available. Other metals, especially copper, are also used. Sheathing or roofing paper may or may not be placed under metal roofing.

Flat or Sheet Roofing.—This roofing comes in sheets. Material may be sheet steel, tin plated, with the underside painted, or copper. The sizes of tinned steel sheets are 14 by 20 in. or 20 by 28 in., the larger sizes being preferred. Common thicknesses or weights are U. S. gage 26, 28, and 29. Weights per square foot for these gages are a little more than the corresponding weights of black finish flat sheets given in Table 10-5. This material may come in boxes of 112 sheets of the 14- by 20-in. size, 56 sheets of the 20- by 28-in. size, or in boxes containing 100 lb. of material. This material may be laid with standing seams or laid flat and soldered.

For a standing-seam roof, 32 sheets of the 20- by 28-in. size or 68 sheets of the 14- by 20-in. size are required per square for covering and laps for seams.

The materials needed for a flat soldered-seam roof are given in Table 10-3. The table gives the number of sheets required, including laps. From 4 to 8 per cent should be added to tabular values for waste of cutting and fitting.

TABLE 10-3.—FLAT SOLDERED-SEAM ROOF. MATERIALS PER SQUARE

Material	Using 14- by 20-in. sheets	Using 20- by 28-in. sheets
Sheets, number........	62	29
Solder, pounds.... . . .	7–9	4–6
Nails, pounds..........	3–5	3–4
Rosin, pounds.........	1	1
Charcoal, pounds......	2	2

This roofing material may cost $12 to $25 per square for standing seams, and $16 to $30 per square for flat soldered seams, including solder and other materials. The material may be priced per sheet, per box, per pound, or per 100 lb., with gage and other details being given. At the present time, tin-plated steel roofing may cost $6 to $8 per 100 lb. at the job.

Copper roofing sheets come in varying sizes and weights. Common weights are 14 or 16 oz. per square foot. The roof may be laid flat or with standing seams. Copper roofing may be laid over roofing paper or light-weight roofing felt. Copper or bronze nails should be used if nailing is required. About 5 per cent should be allowed for waste in addition to laps. Copper roofing may cost $25 to $50 per square.

Crimped and Corrugated Roofing.—Standard sheets of crimped and corrugated-steel roofing are available in rust-resisting alloy steel (copper bearing), open-hearth steel, black (unpainted mill) finish, painted, or galvanized finish. Common gages are 22, 24, 26, 28, and 29 U.S. Standard lengths are 5 to 12 ft., with 1-ft. variations. Standard widths are 26 or 27.5 in., giving a net width of 24 in., allowing for side laps of 2 or 3.5 in. These types of steel roofing are usually priced per 100 lb. with various extras for quantities and gages.

The estimator should consult the material dealer for prices (base prices and extras) in effect at the time the estimate is made. Prices may be f.o.b. mill, f.o.b. nearest railway station, or delivered at job. At the present time, approximate prices per

100 lb. delivered at the job may range from \$4 to \$6 for black (mill) finish and from \$4.50 to \$7 for galvanized.

Many dealers price crimped and corrugated-steel roofing by the sheet, with gage, width, length, finish, and other details given; or by the lineal foot for standard lengths with gage, width, finish, and other details given. This method of pricing is popular in many districts where the roofing is used for barns and other wooden-frame buildings. Prices per lineal foot may range from about \$0.07 to \$0.15 for 26- or 27.5-in. painted material for 26 and 28 gages, and from about \$0.10 to \$0.25 for galvanized material of 26, 28, and 29 gages.

Barbed lead-headed roofing nails about 1.75 in. long should be used for fastening crimped or corrugated-steel roofing to wooden sheathing. From 1 to 2 lb. per square are required. Special ties or clamps are used for fastening this material to steel shapes (purlins, beams, etc.).

Crimped sheets usually have two or more crimps running lengthwise of the sheets. One of the edge crimps should be of a type to reduce possible leakage. Side laps may be 2 to 3.5 in. End laps are usually 6 or 8 in. for roofs and 4 or 6 in. for siding. Extra material for laps will be about 15 per cent with 2-in. side laps and about 22 per cent with 3.5-in. side laps. About 5 per cent should be allowed for cutting and fitting waste in addition to the allowance for laps. Crimped sheets weigh about the same per square as corrugated sheets of the same gage. See Table 10-4 for square feet of corrugated steel required per square of roof surface, see Table 10-5 for weights per square foot, and Table 10-6 for approximate weights of materials required per square.

Corrugated sheets with 1.25- and 2.50- (actually 2.67-) in. corrugations are commonly used for siding and roofing. The 26-in. width usually has both edges turned the same way, and the side lap is about 2.00 in. (about one 2.50-in. corrugation). The 27.5-in. width usually has one edge turned up and the other down, and the side lap is 3.50 in. (about 1.50 times the 2.50-in. corrugations). End lap is about 4 to 6 in. for siding and 6 to 8 in. for roofing. Corrugated roofing should not be used when the pitch is less than 3 in 12. Steel flashing is required on ridges, valleys, eaves, windows, etc., whenever necessary to ensure watertightness.

Approximate gross areas of corrugated sheets required are:

27.5-in. width = net area + end laps + 15 per cent for side laps of 1.5 corrugations.

26-in. width = net area + end laps + 10 per cent for side laps of 1 corrugation.

In general, about 15 per cent is sufficient for end and side laps for the 26-in. width and 22 per cent for the 27.5-in. width. From 5 to 10 per cent in addition may be allowed for waste caused by cutting and fitting.

Table 10-4 gives the square feet of corrugated steel required per square of roof surface.

TABLE 10-4.—APPROXIMATE SQUARE FEET OF CORRUGATED STEEL REQUIRED PER SQUARE

Gross width, in.	Net width, in.	Side lap, in.	End lap, in.				
			4	5	6	7	8
			Square feet for one square				
26	24	2.0	113	114	115	116	117
27.5	24	3.5	120	121	122	123	124

Table 10-5 gives the weights per square foot of flat and corrugated sheets in black (unpainted), painted, and galvanized finishes.

TABLE 10-5.—WEIGHTS OF FLAT AND CORRUGATED STEEL PER SQUARE FOOT

U. S. gage	Thickness, in.	Flat sheets			Corrugated sheets		
		Black	Painted	Galvanized	Black	Painted	Galvanized
22	0.030	1.25	1.26	1.41	1.35	1.36	1.51
24	0.024	1.00	1.01	1.16	1.08	1.09	1.25
26	0.018	0.75	0.76	0.91	0.81	0.82	0.98
27	0.0165	0.69	0.70	0.84	0.74	0.75	0.91
28	0.015	0.63	0.64	0.78	0.67	0.68	0.84
29	0.0135	....	....	0.72	....	....	0.77

To obtain weights per square, multiply the proper tabular value by the number of square feet of steel required per square.

Table 10-6 gives approximate weights per square for 26- and 27.5-in. widths, based on 15 per cent for laps and 5 per cent cutting waste for the 26-in. width and 22 per cent for laps and 5 per cent for cutting waste for the 27.5-in. width.

TABLE 10-6.—APPROXIMATE WEIGHTS OF CORRUGATED STEEL REQUIRED PER SQUARE

U. S. Gage	26-in. Width		27.5-in. Width	
	Black	Galvanized	Black	Galvanized
22	162	181	172	192
24	130	150	137	159
26	97	118	104	125
27	89	109	94	116
28	80	101	85	107
29	...	92	...	98

Weights of painted steel will average 1 to 1.5 lb. per square more than those of the corresponding gage of black-finish steel.

Diagram 10-4 (page 615) may be used for estimating the cost per square of metal roofing.

14. Flashing.—Materials used for flashing may be tinned, painted, or galvanized steel; copper; or asphalt. Metal sheets or shingles about 5 by 7 in. in size are usually used around chimneys and small openings. For valleys (and sometimes for ridges), rolls of metal or asphalt roofing may be used. The cost of metal flashing will depend upon the material, gage, width, and length. Valley strips are usually 12 to 18 in. wide. Ridge strips may be 9 or 12 in. wide. Cost of tinned-steel flashing shingles 7 by 9 in. may vary from about \$1 to \$2 per 100. Cost of copper flashing shingles or strips may vary from \$0.25 to \$0.50 per lb. Steel valley, 14 to 18 in. wide, 28 gage galvanized, comes in rolls about 25 or 50 ft. long. The 25-ft. rolls may cost \$1 to \$2 per roll, depending on width and gage. Asphalt valley strips come in rolls about 18 in. wide and 36 ft. long, and cost about \$1 per roll. Asphalt ridge strips come in rolls about 9 in. wide and 30 ft. long and cost about \$0.50 per roll.

15. Roofing Trim.—Roofing trim such as ridge strips, gutters, and downspouts are usually estimated per lineal foot. Ridge ends (finials), end caps, eaves trough corners, elbows, shoes,

drop outlets, cutoffs, etc., are usually estimated by the piece, other details being given. Hooks, hangers, etc., are listed by the dozen. Approximate prices (1946) are as follows:

Ridge strips, 28-gage galvanized steel........	\$0.40–\$0.85 per 10 lin. feet
Finials...........................	\$0.15–\$0.50 each
Gutters, 26- to 28-gage, galvanized steel, 3.5–6 in..................................	\$0.40—\$1.25 per 10 lin. feet
Rain pipe, 26- to 28-gage, galvanized steel, 3–4 in.................................	\$0.50–\$1.25 per 10 lin. feet
Drop outlets, elbows, shoes, corners, etc......	\$0.15–\$0.65 each
Rain-pipe cutoffs........................	\$0.75—\$1.50 each

These prices are approximate; hence, dealers' price lists should be consulted when preparing estimates. Special work should be estimated separately by a competent tinsmith.

16. Sheet-metal Work.—Frequently most of the items listed under roofing trim are classed as sheet-metal work. These items are purchased ready made from the dealers, and the contractor erects them. On some jobs, the sheet-metal work (providing of the materials and their installation) is let as a subcontract. For estimates on special work such as cornices, skylights, ventilators, and windows, the estimator should consult the manufacturer or dealer and secure his prices.

17. Labor.—The cost of labor for roofing and flashing will depend upon kind of labor (roofers, carpenters, tinsmiths, painters, handy men, helpers, etc.) used, their hourly output, and hourly wages. The hourly output will depend on the particular job (cutting and fitting required, materials to be used, etc.) and upon the skill and inclination of the workers. Labor wages may vary from \$0.65 to \$1.25 per hour for unskilled labor and from \$1 to \$2.25 per hour for skilled labor.

For roofing work, the men should be organized in gangs consisting of both skilled laborers and helpers (if local rules permit the use of helpers). If a gang consists of three or more men, one should be the straw boss, or foreman. The number of men in the gang will vary with the amount of roofing and kind of material. For ordinary shingling or the laying of asphalt roofing, a gang may consist of two to five men. For built-up or composition roofing, one or two men may be needed on the ground for about every two men on the roof. Enough helpers should be available to do the work on the ground and to keep the roof men

supplied with materials. The proportion may vary from about one helper for four roofers to one helper for one roofer. If the gang is large (say five or more men) or if two or more gangs are used on the job, a foreman should be provided to supervise the work and keep the men busy.

TABLE 10-7.—APPROXIMATE LABOR-HOURS REQUIRED PER SQUARE FOR APPLYING ROOFING MATERIALS

Roofing materials	Hours per square	
	Simple roofs	Complex roofs
Shingles, wood, single	2– 6	5–10
Asphalt, single	2– 6	5–10
Asphalt, 3 and 4 strip	1– 4	3– 6
Asbestos, single	3– 8	5–12
Slate, single	3– 8	5–12
Metal, single	3– 6	5–10
Tile, clay	4–10	6–16
Metal	3– 9	6–15
Asphalt roll roofing	0.5– 2	1– 3
Canvas, laying canvas	1.5– 2.5	
Painting, per coat	0.5– 1.5	
Composition felt and tar or asphalt:		
2-ply and 2-coat	2 – 4	
2-ply and 3-coat	2.5– 5	
3-ply and 3-coat	3 – 6	
3-ply and 4-coat	3.5– 7	
4-ply and 4-coat	4 – 8	
4-ply and 5-coat	4.5– 9	
5-ply and 5-coat	5 –10	
1 coat gravel or slag	0.5– 1.5	
1 coat tar or asphalt	0.5– 1.5	
Metal, tinned, soldered, 14 × 20	6 – 9	8–14
20 × 28	4 – 7	6–10
Tinned, seamed, 14 × 20	5 – 7	6–12
20 × 28	3 – 6	5– 9
Crimped and corrugated on wood sheathing	0.5– 1.5	1– 3
On metal frame	1.0– 2.5	2– 5
Roofing paper and felt	0.5– 1.5	1– 2.5

Tables 10-7 and 10-8 give approximate labor required for different kinds of roofing and flashing work. The labor-hours given refer to work on buildings of about two or three stories or less in height. For multistoried buildings, additional labor time

must be allowed for hoisting materials to the roof. From 0.2 to 0.5 additional labor-hours per square per story may be required, depending on the materials used and hoisting equipment available. If materials have to be carried by the men, 0.4 to 1.0 additional labor-hours per square per story may be needed.

TABLE 10-8.—APPROXIMATE LABOR-HOURS REQUIRED FOR ROOF FLASHING AND TRIM

Kind of work	Unit of measurement	Labor-hours
Ridges	100 lin. ft.	1 – 3
Valleys	100 lin. ft.	1 – 3
Flashing	100 lin. ft.	3 –10
Flashing	100 shingles or pieces	3 – 8
Gutters	100 lin. ft.	2 – 5
Downspouts	100 lin. ft.	2 – 5
Miscellaneous items	Each	0.1– 1.0

When the sheet-metal work is let as a subcontract, the estimator may use the subcontractor's figures and will not need to make his own estimate of materials and labor for this work.

Diagram 10-6 (page 617) may be used for estimating labor costs of roofing per square or per 100 lin. ft.

18. Equipment.—The equipment required will vary with the kind of roofing and the conditions on the particular job.

Shingling. Hand tools, strips for footholds, ladders, and sometimes hoists and scaffolds.

Tile. About the same as for shingling job.

Asphalt roll. Hand tools, including brushes, ladders, sometimes special shoes with rubber or nonskid soles, and sometimes hoists and scaffolds.

Canvas. Hand tools, ladders, painting tools.

Composition. Hand tools, brushes, heaters, pails, ladders, and sometimes hoists.

Metal. Hand tools including metal shears, special tools for bending seams, soldering outfits, ladders, and sometimes scaffolds and hoists. Corrugated and crimped roofing will not require seaming or soldering tools.

Roofing paper and felt. Hand tools, ladders, and sometimes scaffolds and hoists.

Overhead costs are usually higher for roofing than for other carpenter work because of the higher rates for compensation insurance. About 40 per cent of all labor costs will be assumed for overhead, or 40 per cent of \$60 = \$ 24

Equipment costs will be low for a job of this size. About \$7 will be assumed for roofing and \$3 for eaves troughs and downspouts = \$ 10

Profit will be taken as 10 per cent of all other costs. 10 per cent of \$307 = 31

Total estimate = \$338

This estimate may be tabulated as follows, using 13.3 squares of roofing and 232 lin. ft. of trim.

Item	Eaves troughs and downspouts		All roofing		Total
	Per 100 lin. ft.	Total	Per square	Total	
Materials	\$13.37	\$31	\$13.68	\$182	\$213
Labor	3.02	7	3.98	53	60
Equipment	1.29	3	0.53	7	10
Overhead	1.29	3	1.58	21	24
Profit	1.73	4	2.03	27	31
Total	\$20.70	\$48	\$21.80	\$290	\$338

Usually, this estimate would be divided into one for the roofing and another for the eaves troughs and downspouts, as indicated in the tabulation.

Diagrams 10-5 and 10-6 may be used for checking material costs for shingles and labor costs per square if desired.

Asphalt-strip Shingle Roof.—Prepare a cost estimate of covering the residence roof in the preceding illustrative estimate, using a good grade of asphalt-strip shingles (three tab) and placing a layer of roofing paper between the wooden sheathing and the shingles. Cost of eaves troughs and downspouts will be the same as before and will not be repeated here.

Materials. Area = 1,330 sq. ft., or 13.3 squares. Price of shingles of grade selected by owner is \$2.75 per bundle covering 33⅓ sq. ft., or \$8.25 per square. Bundles required = 13.3 × 3 = 39.9, or 40.

Allowing 7 per cent for waste, fitting, and 2 layers at eaves, bundles required will be 43. \$2.75 × 43	= \$118
Nails at about 4 lb. per square. 4 × 13.3 × \$0.06	= 4
Flashing around chimney, say	= 1
Metal ridge, as before	= 4
Roofing felt, 13.3 squares will take 4 rolls of 432 sq. ft. each at \$2.45 per roll for the 15 lb. weight	= 10
Tacks for the felt, at \$0.15 per square	= 2
Roofing materials	\$139

Labor. About 4 hr. of labor per square should be sufficient for laying roofing paper, strip shingles, flashing and metal ridge. Labor cost = \$1 × 4 × 13.3	= \$ 53
Overhead at 40 per cent of labor cost of \$53	= 21
Equipment, about	= 7
Profit at 10 per cent of \$220	= 22
Total cost	= \$242

This may be tabulated as follows, using 13.3 squares of roof.

Item	Cost per Square	Total Roofing Cost
Materials	\$10.46	\$139
Labor	3.98	53
Equipment	0.53	7
Overhead	1.58	21
Profit	1.65	22
Total	\$18.20	\$242

If desired, Diagram 10-2 may be used for checking shingle costs per square and Diagram 10-6 for labor costs per square.

Asphalt-roll Roof.—Prepare a cost estimate for covering a barn roof measuring 44 by 96 ft. over all with 65-lb. mica-finished asphalt roofing laid directly on wooden sheathing. Cost of roofing per roll with nails and roofing cement included is \$2.65 per roll of 108 sq. ft. delivered at the job.

Materials. Roof area = 44 × 96 = 4,224 sq. ft., or 42.24 squares. Allow about 4 per cent for end laps, extra lap at ridge, and for edges and waste. This gives 42.24 × 1.04, or about 44 squares. Cost of materials = \$2.65 × 44	= \$117
Labor. This material may be laid quite rapidly on a simple roof. About 1 hr. per square should be sufficient, or 42.25 labor-hours. By assuming 1 carpenter at \$1.25 per hour and 1 helper at \$0.75 per hour, labor cost will be ½(\$1.25 + \$0.75) × 42.25 squares	= 42
Equipment cost will be small, say	= 4
Overhead, at 35 per cent of labor cost	= 15
Profit, say 8 per cent of all other costs (\$174)	= 14
	= \$192

This may be summarized as follows for 42.25 squares:

Item	Cost per Square	Total Cost
Materials	\$2.77	\$117
Labor	1.00	42
Equipment	0.10	4
Overhead	0.35	15
Profit	0.33	14
Total	\$4.55	\$192

If desired, Diagram 10-1 may be used for checking the materials cost per square, and Diagram 10-6 the labor costs.

Corrugated-steel Roof.—Prepare a cost estimate for covering the barn roof of the preceding illustrative estimate with corrugated galvanized-steel roofing of No. 28 gage and 26 in. wide. The roof is 96 ft. long and has a central ridge running lengthwise. No. 28 gage corrugated galvanized roofing 26 in. wide costs \$0.125 per lineal foot in standard lengths, delivered at the job. Lead-headed nails 1.75 in. long cost \$0.18 per pound. Galvanized ridge costs \$0.80 per 10 lin. ft. Finials or ends cost \$0.35 each.

Materials. The length of roof from eaves to ridge is 44 ÷ 2, or 22 ft. This length will take one 12-ft. length and one 11-ft. length, will allow for more than enough end lap, and will permit the ends to extend an inch or so beyond the sheathing at the eaves.

Number of 12-ft. strips will be (96 ÷ 2 ft. net width) × 2 sides = 96

Number of 11-ft. strips will be (96 ÷ 2 ft. net width) × 2 sides = 96

Total lineal feet of corrugated steel = 96 × 12 + 96 × 11 = 2,208 ft.

Cost of corrugated-steel roofing = \$0.125 × 2,208	= \$276
Length of ridge = 96 ft. Use 10 strips 10 ft. long, allowing for laps. Use 2 ends or finials. Cost will be \$0.80 × 10 + \$0.35 × 2	= 9
Nails, say 50 lb. at \$0.18	= 9
Total materials	= \$294

Labor. Labor may be estimated per sheet, per square, or per 100 lin. ft. About 1 hr. per square or about 2 hr. per 100 lin. ft. should be sufficient as no cutting or fitting is required.

2,208 lin. ft. at 2 hr. per hundred gives 44 hr.

Add 1 hr. for ridge. Total labor = 45 hr.

This job could be handled by 1 metalworker and 1 helper or by 2 metalworkers. Assuming 1 metalworker at \$1.25 per hour and 1 helper at \$0.75 per hour, the labor cost will be

½(1.25 + 0.75) × 45 hr.	= \$ 45
Equipment costs for this job should be low, say	= 4
Overhead at 35 per cent of labor costs of \$45	= 16
Profit at 8 per cent of other costs (\$359)	= 29
Total cost	= \$388

This estimate may be itemized as follows for 42.25 squares:

Item	Cost per Square	Total Cost
Materials	\$6.96	\$294
Labor	1.07	45
Equipment	0.10	4
Overhead	0.38	16
Profit	0.69	29
Total	\$9.20	\$388

CHAPTER XI

LATHING AND PLASTERING

A. LATHING

1. Lathing.—Lathing estimates include materials, labor, equipment, overhead, and profit. The unit of measurement for lathing work is usually the square yard (9 sq. ft.), though in some instances such units as the square foot, 100, or 1,000 sq. ft. of surface area; the square yard or 100 sq. yd. of surface area; 100 or 1,000 wood lath; 1 or 100 sq. ft., one piece, or 100 lb. of wire lath; one piece or 100 sq. ft. of surface area of plaster board have been used. Furring, corner bead, etc., is usually estimated by the lineal foot, 100 lin. ft. being common. When preparing lathing estimates, the estimator should be familiar with the local trade practices.

2. Materials. *Wood Lath.*—Wood lath vary in price according to time, locality, kind of wood, and width and length of lath. Wood lath are usually sold by the thousand or by the bundle of 100 lath. Common lengths are 32 and 48 in., stated widths are 1 and 1.5 in. (actual widths ⅞ and 1⅜ in.), and thicknesses are 0.25 and 0.375 in. The most common size appears to be 0.375 by 1.375 in. in size (sometimes called ⅜ by 1½) and 48 in. in length. Lath are usually placed ⅜ in. apart so that a 1⅜-in. lath covers 1¾ in., and the ⅞-in. lath covers 1¼ in. As the lathing area is usually "taken off" in square yards, the number of lath required per square yard must be known. Prices of wood lath may vary from about $9 to $30 per 1,000 lath, depending on width, thickness, length, and quality. When preparing the estimate, prices should be obtained from the dealers from whom the lath is to be purchased. The nails are usually of 3d (3 penny) weight, and blued finish is preferred. These nails will average about 600 or a little more to the pound.

Table 11-1 gives the sizes of wood lath, the number required per square yard, and the nails required per 1,000 lath. If the net yardage (all openings deducted) is given in the take-off,

5 to 10 per cent should be allowed for lath waste. If small openings are not deducted, then no waste allowance need be added for the lath. The quantities of nails specified allows for waste.

TABLE 11-1.—WOOD-LATH MATERIALS

Size of lath, inches	Nailing centers, inch	Lath per square yard	Nails, pounds per 1,000 laths	Nails, pounds per square yard
1 by 32	16	26	7	0.18
1 by 48	12	20	13	0.26
1 by 48	16	20	10	0.20
1.5 by 48	12	15	13	0.20
1.5 by 48	16	15	10	0.15

Plaster Board.—Plaster board comes in various sizes and thicknesses. Common thicknesses are ¼, ⅜, and ½ in., widths are 18, 24, 32, 36, and 48 in., and lengths are from 2 to 12 ft. The width or length should be such that the boards will fit 12- and 16-in. nailing centers without cutting and waste. The size should be such that one board may be readily applied by one man. Weights may vary from 6 to 25 lb. per square yard, depending on material and thickness. If net areas are given in the take-off, 5 to 15 per cent should be allowed for waste. The waste will increase with the number of openings and jogs to be framed.

Plaster board may be sold by the board (thickness, length, and width specified) or by 1,000 sq. ft. with thickness given. Prices per 1,000 sq. ft. vary from about $30 to $80, depending on thickness and quality. Finishing nails about 3d (3 penny) weight are often used. From 0.15 to 0.18 lb. of nails will be required per square yard for nailing centers 16 in. apart, and from 0.20 to 0.24 lb. of nails per square yard for 12-in. nailing centers, with allowance for waste.

Estimates for plaster board are usually based on the square yard, though the square foot, square of 100 sq. ft., or 1,000 sq. ft. may be used.

Metal Lath.—The general function of metal lath is to form a support, background, or base on which plaster or stucco may be

100 sq. yd. for the 2.2 lb. per square yard weight, and from \$20 to \$45 per 100 sq. yd. for the 3.4 lb. per square yard weight, depending upon whether the lath is painted or galvanized and upon the locality. At the present time 1946), approximate prices of diamond-mesh metal lath are as follows:

Kind	Weight per sq. yd., pound	Cost per 100 sq. yd.
Painted black	2.2	\$18–35
Painted black	3.0	25–40
Galvanized	2.5	25–40
Galvanized	3.4	30–45

The metal lath may be applied to wooden studs and beams, to wood furring strips, or to metal furring strips. If furring is required, this is usually estimated separately.

For ordinary metal lath applied to wood, about 1 lb. of nails or staples will be required for each 15 to 20 sq. yd. of lath. The nails should be about 1 in. long and should have large flat heads, say about ½ in. in diameter. Nails should be spaced about every 6 in. Some constructors tie the sheets of metal lath about every 6 or 8 in. along the laps, using a galvanized wire of about No. 18 gage.

Galvanized metal lath of the heavier weight should be used for exterior plastering and stuccowork.

When the expanded metal lath is carefully bent around corners and all joints (especially at corners) are lapped and wire tied, no corner reinforcement is required.

When manufacturing expanded metal lath, the sheets are usually cut to some exact size, though sometimes the sheets are made or cut a little large to allow for laps of about 1 in. The length of the sheets is 8 ft. and the widths vary.

Furring.—Wooden or metal furring may be required when lath is to be placed on brick or concrete walls. Wooden furring usually consists of 1- by 2-in. strips of pine or spruce spaced 12 or 16 in. on centers. Both wood and metal lath may be applied to wood furring. The wooden furring is usually estimated per 100 lin. ft., about 11 lin. ft. with 12-in. spacing, or

8 lin. ft. with 16-in. spacing, being required per square yard of lath, with allowance for waste.

Metal furring may consist of ¾-in. steel channels fastened to the masonry or other surface by hangers or bars or plugs, as the case may be. From 5 to 15 lb. of metal furring may be required for each square yard of metal lath, depending on the amount and complexity of the framing. About 10 per cent should be allowed for waste.

Grounds.—Grounds are wooden strips, usually about 1, 2, or 3 in. in width and of varying thicknesses, depending on the thickness desired for the lath and plaster. Common thicknesses of grounds are about as follows:

Item	Plaster, coats	Grounds, inches
Wood lath	2	⅝, ¾, ⅞
	3	¾, ⅞, 1
Metal lath	3	⅝, ¾
Brick and tile	2	⅝
	3	⅝, ¾
Plaster board	2	⅝ to 1
	3	¾ to 1¼

Grounds are carefully placed around all openings and along the bottom of walls near the floor so as to serve as a guide for the surface of the plaster. Grounds are placed directly on the framing in wood construction, and the lath or plaster board butts up against the grounds. Sometimes the grounds are placed over the plaster board. Grounds are usually placed over the brick or tile in this type of construction.

Corner Beads.—Corner beads are frequently used to protect all corners and edges. Metal corner bead is usually priced per 100 lin. ft. Standard corner bead comes in 6, 8, or 10 ft. lengths and may cost $3 to $5 per 100 lin. ft. Expansion corner bead may cost $4 to $6 per 100 lin. ft.

Corner Reinforcement.—Corner reinforcement, made of strips of expanded metal lath may cost $2 to $4 per 100 lin. ft. Corner reinforcement is usually required when wood lath or plaster board at base is used. It is not required with expanded metal lath when this lath is bent or lapped and wire tied at the corners.

Diagrams.—Diagrams 11-1, 11-2, and 11-3 (pages 618, 619, and 620) may be used for estimating lathing materials. The diagrams for wood lath and plaster board include a reasonable allowance for nails.

3. Labor.—Labor costs of lathing will depend upon the time in hours required per square yard and the hourly labor wage. Hourly wages for lathers may vary from about $1 to $2. Frequently, the labor cost of lathing is based on the square yard, allowing a certain price per square yard for ordinary work with extras for special work.

Wood lath are usually applied by skilled lathers. If the applying is done by carpenters, the time for applying 1,000 lath should be increased from 25 to 40 per cent, depending on the skill of the carpenter employed. The number of lath applied per hour will depend on the skill of the lathers, and on the particular job.

When the labor cost of lathing is based on the area or on the number of lath, it is necessary to know how the yardage or number of lath is computed. Trade practices vary in different localities. The measurement of yardage may be based upon the following:

1. Gross area. No deductions for openings.
2. Net area. All openings deducted.
3. Gross area less certain deductions. For example, in a certain locality no opening of less than 2 sq. yd. is deducted. In another locality, openings less than 2 ft. wide are not deducted. In another location, half of the openings larger than 2 sq. yd. are deducted.
4. Flat and curved work. Curved work is often estimated to cost twice as much as flat work.

It is necessary for an estimator to study the practices in the place in which the job is located, and to govern himself accordingly when the work is to be sublet or paid for on a unit-price basis.

If the contractor intends to employ the lathers himself and wishes to estimate accordingly, he should consider the actual net areas and make allowances for corners and other items.

There are so many kinds of metal lath that it is almost impossible to give accurate information in regard to the labor time required for applying every kind of metal lath under all the different conditions. The labor of applying metal lath will vary

with the difficulty of handling the materials, depending on the kind of lath and the gage or weight.

Wood furring and grounds are usually placed by carpenters. Metal furring and grounds may be placed by carpenters or lathers. Lathers usually place the corner bead and corner reinforcement.

The following tables give approximate labor-hours required for applying different kinds of lath and furring.

TABLE 11-2.—LABOR REQUIRED FOR APPLYING WOODEN LATH

Size of lath, in.	Nailing centers, in.	Lath per hr.	Hours per 1,000 lath	Sq. yd. per hr.	Hr. per 100 sq. yd.
1 by 32	16	150–250	4.0– 6.7	6.0–10.0	10–17
1 by 48	12	100–200	5.0–10.0	5.0–10.0	10–20
1 by 48	16	125–225	4.5– 8.0	6.0–11.0	9–17
1.5 by 48	12	90–175	5.5–11.0	6.0–11.5	9–17
1.5 by 48	16	105–200	5.0– 9.5	7.0–13.0	8–15

TABLE 11-3.—LABOR REQUIRED FOR APPLYING PLASTER BOARD

Nailing centers, in.	Hr. per 1,000 sq. ft.	Sq. ft. per hr.	Sq. yd. per hr.	Hr. per 100 sq. yd.
12	9–19	55–110	6–12	8–17
16	8–17	60–135	7–15	7–15

TABLE 11-4.—LABOR REQUIRED FOR APPLYING METAL LATH ON WOOD FURRING

Kind of work	Sq. yd. per hr.		Hr. per 100 sq. yd.	
	12-in. nailing centers	16-in. nailing centers	12-in. nailing centers	16-in. nailing centers
Walls and partitions	7–10	9–13	10–15	8–11
Columns	3– 4	4– 5	24–32	20–25
Flat ceilings	5– 9	8–12	10–18	8–12
Paneled, arched, or groined ceilings	5– 7	6–10	14–20	10–16
Beams and girders	3– 4	4– 5	24–32	18–26
Simple coves and cornices	3– 5	4– 7	21–30	15–24
Complex cornices	3– 4	3– 5	25–35	20–30

TABLE 11-5.—LABOR REQUIRED FOR APPLYING METAL LATH ON METAL FURRING

Kind of work	Sq. yd. per hr.		Hr. per 100 sq. yd.	
	12-in. nailing centers	16-in. nailing centers	12-in. nailing centers	16-in. nailing centers
Walls and partitions	5–10	8–11	10–18	9–13
Columns	3– 4	3– 5	25–35	20–30
Flat ceilings	5– 8	7–10	12–20	10–15
Paneled, arched or groined ceilings	4– 7	5– 8	15–24	12–18
Beams and girders	3– 4	4– 5	24–32	20–25
Coves and cornices	3– 5	4– 7	22–30	15–24
Complex cornices	3– 4	3– 5	25–35	20–30

TABLE 11-6.—LABOR REQUIRED FOR APPLYING FURRING AND GROUNDS

Kind of work	Hr. per 100 lin. ft.	Hours per 100 lb. of metal	Hr. per 100 sq. yd.	
			12-in. nailing centers	16-in. nailing centers
Wood furring on wood	1.0–1.6	....	9–18	7–14
Wood furring on brick or tile	1.5–3.0	....	16–35	12–25
Metal furring, alone (¾-in. channel)	1.5–3.0	3– 6	16–35	12–25
Metal furring, with ties and bars	3.0–5.0	8–12	35–55	25–40
Wood grounds	1.5–4.0			
Metal corner beads	3.0–5.0			
Metal corner reinforcement	2.0–3.5			

Diagrams.—Diagram 11-4 (page 621) may be used for estimating labor costs of lathing, and Diagram 11-5 (page 622) for labor costs of placing, furring, corner beads, and reinforcement when reasonable rates of work may be assumed.

4. Equipment.—Wooden horses, platforms, plank, and scaffolding are required on all lathing jobs. The proportionate cost (depreciation and repairs) of this equipment should be charged to the job. Transportation costs to and from the job must be included. If scaffolding is to be erected and taken down by other labor, this labor cost must be included. For a small lathing

job, like that for a residence, probably an allowance of $5 for the material and $10 for trucking would be enough. For metal lath and furring, metal punching shears and perhaps bending and other special tools will be needed. The costs of such tools should be included in the estimate.

5. Overhead and Profit.—Overhead on lathing jobs is usually based on labor costs and may vary from about 20 to 40 per cent of labor costs, or from 10 to 25 per cent of the cost of materials and labor.

Profit may range from about 5 to 15 per cent of all other costs.

6. Lathing Estimates.—The estimate for the total cost of lathing should include the following:

Materials. Lath, nails, and staples. Plaster board and nails. Corner beads and corner reinforcement. Furring, if this must be provided. Proper allowances must be made for waste.

Labor. All labor including helpers and foreman (if provided).

Equipment. All equipment costs.

Overhead. Based on labor costs or on the sum of material and labor costs.

Profit.

Unit costs per square yard should also be computed based on the actual net yardage. Unit costs per 1,000 lath, or per square of 100 sq. ft. may be computed if desired.

7. Illustrative Estimate.—Prepare a lathing estimate (1) with wood lath, (2) with plaster board, and (3) with wire lath, for the downstairs rooms of a residence. The dimensions of the rooms and openings are as follows:

Living room:	12 by 20 by 8.5 ft. high.
	2 triple windows, 5 by 8 ft. each.
	2 windows, 3 by 5 ft. each.
	1 double door, 5 by 7 ft.
Dining room:	12 by 14 by 8.5 ft. high
	1 triple window, 5 by 8 ft.
	1 double door, 5 by 7 ft.
	1 single door, 3 by 7 ft.
Kitchen:	10 by 12 by 8.5 ft. high.
	1 double window, 5 by 5 ft.
	2 doors, 3 by 7 ft. each.
Hall:	8 by 10 by 8.5 ft. high.
	2 double doors, 5 by 7 ft. each.
	1 outside door, 3.5 by 7 ft.
	1 closet door, 2.5 by 7 ft.
Closet:	4 by 4 by 8.5 ft. high.
	1 door, 2.5 by 7 ft.

The following data are assumed:

Wage of lathers is \$1.20 per hour.
An allowance of \$15 for equipment.
An allowance of 28 per cent of labor costs for overhead.
An allowance of 8 per cent of all other costs for profit.
Grounds were placed by carpenters.
Nailing centers are of wood and are spaced 16 in. on centers.
No furring is required. No corner bead required.
Corner reinforcement required for all corners without exception.
Prices of materials are as follows:
Wood lath, ⅜ by 1.5 by 48 in., \$16 per 1,000 lath.
Plaster board, 2 by 4 ft. with grooved edges, \$48 per 1,000 sq. ft.
Wire lath, 2.2 lb. per square yard, black painted, \$32 per 100 sq. yd.
Corner reinforcement expanded metal lath, \$2.25 per 100 lin. ft.
Corner bead, \$3.50 per 100 lin. ft.
Nails, \$0.055 per pound.

Results wanted are the costs of materials, labor, equipment, overhead, profit, and totals per square yard and for the job.

Solution:

Yardage equals

Room	Walls		Ceiling		Openings		Net
Living room,	60.5	+	26.7	−	16.1	=	71.1 sq. yd.
Dining room,	49.1	+	18.7	−	10.7	=	57.1
Kitchen,	41.6	+	13.3	−	7.5	=	47.4
Hall,	34.0	+	8.9	−	12.4	=	30.5
Closet,	15.1	+	1.8	−	2.0	=	14.9
Total						=	221.0 sq. yd.

1. Wood lath. Number = 15 × 221 = 3,315.

Add 10 per cent for waste, giving a total of 3,650 lath at \$16 per 1,000	= \$ 59
Nails at 10 lb. per 1,000 lath, say 37 lb. at \$0.055	= 2
Corner reinforcement = 98 + 86 + 78 + 70 + 50 = 382 ft.	
Allow about 5 per cent for waste, giving about 400 lineal feet at \$2.25 per 100	= 9
No corner bead needed.	
Total materials	= \$ 70
Labor installing lath at about 7 hr. per 1,000 lath, or about 11 hr. per 100 sq. yd., will require about 24 hr.	
Labor applying corner reinforcement at about 2.5 hr. per 100 lin. ft. will require about 10 hr.	
Total labor = 34 at \$1.20	= \$ 41
Equipment, as stated	= 15
Overhead, 28 per cent of \$41, or	= 11
Profit, 8 per cent of all other costs, or	= 11
Total estimated cost of wood lath	= \$148

A unit cost of $0.67 per square yard.
This is high because of the corner reinforcement required.

2. Plaster board, 221 sq. yd. = 1,989 sq. ft.
Adding 10 per cent for waste gives about 2,200 sq. ft.

Cost of plaster board at $48 per 1,000 sq. ft.	= $106
Nails, about 37 lb. at $0.055	= 2
Corner reinforcement as before	= 9
Total materials	= $117
Labor, say 10 hr. per 100 sq. yd. will require 22 hr.	
Labor applying corner reinforcement, probably a little less than before, say 8 hr.	
Total labor = 30 hr. at $1.20	= $ 36
Equipment, as stated	= 15
Overhead, 28 per cent of $36	= 10
Profit, 8 per cent of $178	= 14
Total	= $192

A unit cost of about $0.87 per square yard

3. Metal lath, 221 sq. yd. Add 12 per cent for waste and laps, giving a total of 247 sq. yd.

247 sq. yd. at $32 per 100 sq. yd.	= $ 79
Nails, 1 lb. for every 15 sq. yd., say 15 lb. at $0.055	= 1
Corner reinforcement, is not needed	
Total materials	= $ 80
Labor, about 11 hr. per 100 sq. yd. of surface, will require 24 hr. This allowance is a little high to allow for bends and laps at corners.	
Total labor 24 hr. at $1.20	= $ 29
Equipment, as stated	= 15
Overhead, 28 per cent of $29	= 8
Profit, 8 per cent of $132	= 11
Total	= $143

Unit cost of about $0.65 per square yard.
These three estimates may be summarized for comparison.

Item	Cost per square yard			Total costs		
	Wood lath	Plaster board	Metal lath	Wood lath	Plaster board	Metal lath
Materials.......	$0.317	$0.529	$0.362	$ 70	$117	$ 80
Labor..........	0.185	0.163	0.132	41	36	29
Equipment......	0.068	0.068	0.068	15	15	15
Overhead.......	0.050	0.045	0.036	11	10	8
Profit..........	0.050	0.053	0.050	11	14	11
Total..........	$0.670	$0.868	$0.648	$148	$192	$143

Note that if corner reinforcement was not used, the total estimates for the wood lath and plaster board would be reduced about \$24 and \$21, respectively.

If desired, the unit costs of materials and labor may be found from Diagrams 11-1 to 11-5.

Diagram 11-1 gives the unit cost of wood lath and nails (1.5 by 48 in. with 10 per cent waste at \$16 per 1,000) as \$0.275 per square yard. For 221 sq. yd., $\$0.275 \times 221 = \$61$ for lath and nails, compared with \$61 in the numerical estimate.

The unit cost of plaster board and nails is given in Diagram 11-2 as \$0.485. For 221 sq. yd., $\$0.485 \times 221 = \$107$, compared with \$108.

The unit cost of metal lath and nails is given in Diagram 11-3 as \$0.37 per square yard. $\$0.37 \times 221 = \$82$ compared with \$80.

Labor costs for wood lath, at 11 hr. per 100 sq. yd., is given in Diagram 11-4 as \$0.132 per square yard. For corner reinforcement, Diagram 11-5 gives, for 2.5 hr. per 100 lin. ft., \$0.03 per lineal foot.

$$\text{Total labor cost} = \$0.132 \times 221 + \$0.03 \times 400 = \$29 + \$12 = \$41,$$

which agrees with computations.

Labor costs for plaster board at 10 hr. per 100 sq. yd. is given in Diagram 11-4 as \$0.12 per square yard. For corner reinforcement, Diagram 11-5 gives, for 2 hr. per 100 lin. ft., \$0.024 per lineal foot.

$$\text{Total labor cost} = \$0.12 \times 221 + 0.024 \times 400 = \$26.50 + 9.50 = \$36,$$

which agrees with the computed value.

Labor costs for metal lath, at 11 hr. per 100 sq. yd., is given in Diagram 11-4 as \$0.132 per square yard. Total labor cost $= \$0.132 \times 221 = \$29$, which agrees with the computed value.

B. PLASTERING

8. Plastering.—Plastering estimates include materials, labor, equipment, overhead, and profit. The unit of measurement for plastering is usually the square yard (9 sq. ft.), though sometimes the square foot or square of 100 sq. ft. is used. The yardage may be based on net area, on gross area, or on gross area less large openings, with allowances for special and difficult work. The unit of measurement for special molding is usually the lineal foot, with width given. When the molding is over 1 ft. wide, or when the molding extends over a considerable area, the square foot or square yard may be selected as a unit. When preparing plastering estimates, the estimator should be familiar with the local trade practice.

Plastering work may be classified as to interior or exterior work, as to the number of coats applied (one, two, or three), as

to the materials used, as to the surface finish, or as to the type of surface on which the plaster may be applied.

The cementing materials for interior plaster are usually lime, gypsum, and plaster of paris. For exterior plaster, or "stucco," portland cement or magnesite may be used.

When plaster is applied to lath, three coats (scratch, brown, and finish) are usually required, though in some instances only two coats are used. When applied to brick, tile, or plaster board, two coats (brown and finish) are usually sufficient, though in some instances one coat or three coats may be required. Sometimes state or loal codes specify the number of coats to be used.

9. Materials.—There are a number of "plasters" and plastering materials on the market, each of varying cost, different covering capacity, and different method of application. There are also a large number of plaster finishes. As it is obviously impractical to attempt to discuss all these in this text, only the more common types will be considered.

Before preparing material estimates for plastering, the estimator should familiarize himself with the various kinds of plaster materials available in his market, their cost, covering capacity, workability, etc.

Interior Plaster.—In three-coat work, applied to wood and metal lath, the scratch coat must be sufficient to fill the space between the lath, form clinches back of the lath, and cover the front of the lath. The thickness of the front covering may vary from about $\frac{1}{16}$ to $\frac{1}{8}$ in. for wire lath to $\frac{1}{8}$ to $\frac{1}{4}$ for wood lath. When applied to plaster board or to brick or tile, the thickness is about $\frac{1}{4}$ in. The brown coat in three-coat work is usually $\frac{1}{4}$, $\frac{5}{16}$, or $\frac{3}{8}$ in. thick, the $\frac{1}{4}$-in. thickness being common. The finish coat may be $\frac{1}{16}$ or $\frac{1}{8}$ in. thick, the $\frac{1}{8}$-in. being preferred.

In two-coat work, the base or scratch coat may vary in thickness from $\frac{1}{4}$ to $\frac{3}{8}$ in. Enough material must be provided to give this thickness and to fill spaces and form clinches when placed on lath. The finish coat may be $\frac{1}{16}$ to $\frac{1}{8}$ in. thick.

The sum of the thicknesses of the plaster coats plus the thickness of the lath or plaster board (if used) must be equal to the thickness of the grounds.

When computing quantities of plaster for the scratch coat, no allowance may be made for the space occupied by metal lath as this is offset by the plaster required for clinching, an allowance

equal to half the thickness of the wood lath may be made and have enough plaster to fill spaces between the lath and to form clinchers, and an allowance equal to the thickness of the plaster board may be made when this plaster-board butts against the grounds.

The mix used for the scratch coat is usually a 1 to 2 or a 1 to 3 mix by volume. When patent hard wall, gypsum, and other prepared plasters weighing about 100 lb. per cubic foot are used, a 1 to 2 or a 1 to 3 mix by weight is equally satisfactory. The richer mix (1 to 2) is often preferred on account of its greater strength.

The mix for the brown coat (in three-coat work) may be a 1 to 2 or a 1 to 3 mix by volume, or a like mix by weight when the cementing material weighs about 100 lb. per cubic foot. The 1 to 3 mix is preferred by many, though other plasterers prefer to keep the mixes the same for both the scratch and brown coats.

The mixes for the finishing coats vary considerably. For a white lime finish, a volume mix of 2 parts lime to 1 part plaster of paris may be used, or a weight mix of about 2 lb. hydrated lime to 1 lb. plaster of paris. In using a gypsum or other prepared plaster and sand finish, the proportions are about 1–2 either by volume or by weight.

Tables 11-7 and 11-8 give information as to the quantities of material required for various plaster coats of varying thickness for 100 sq. yd. of plaster surface. By allowing about 6.7 per cent for waste and unevenness of surface, about 5 cu. ft. of material will be required per 100 sq. yd. of surface for each $\frac{1}{16}$ in. thickness of plaster.

TABLE 11-7.—APPROXIMATE QUANTITY OF PLASTER REQUIRED PER 100 SQ. YD. OF SURFACE

Thickness of plaster, in.	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Cu. ft. of plaster	5	10	15	20	25	30	40	50	60	70	80
Cu. yd. of plaster	0.19	0.37	0.56	.74	.93	1.10	1.50	1.85	2.25	2.60	2.95

Table 11-9 gives information as to quantities of materials required for plaster mixes. As measurement by weight is more accurate than by volume, the weights are given. Hydrated

lime may come in bulk (ton lots), in 50-lb. sacks, or in barrels. Gypsum and other plaster cement usually comes in 100-lb. sacks. Plastering sand may weigh 2,400 to 2,700 lb. per cubic yard. Tabulated values are based on sand weighing about 100 lb. per cubic foot. Hydrated lime, gypsum, and prepared plaster may weigh 50 to 80 lb. per cubic foot.

TABLE 11-8.—APPROXIMATE QUANTITY OF PLASTER REQUIRED FOR FILLING SPACES IN LATH AND PROVIDING CLINCHERS FOR 100 SQ. YD. OF SURFACE

Lath	Size	Cubic feet of plaster	Cubic yards of plaster
Wood lath	¼ by 1 in.	12	0.45
	⅜ by 1 in.	18	0.67
	¼ by 1½ in.	9	0.33
	⅜ by 1½ in.	14	0.52
Metal lath	3⁄16 in. thick	15	0.56
	¼ in. thick	20	0.74
	5⁄16 in. thick	25	0.93
	⅜ in. thick	30	1.10

When estimating materials for interior plaster, consideration must be given to the number of coats, the thickness of lath or plaster board, the thickness of the grounds, and the mixes to be used. Then the thickness of each coat may be assumed, the number of cubic feet (or cubic yards) per 100 sq. yd. of surface for each coat found from Tables 11-7 and 11-8, and the quantities of materials from Table 11-9. Then the various quantities (and their costs) required per 1 or 100 sq. yd. and the totals for the job may be tabulated.

There are so many kinds, varieties, and designs of ornamental plastering on the market that it is impractical to prepare any tables or diagrams for this kind of work. The quantities of materials can best be estimated after the plans and specifications have been carefully studied. The quantity of plaster may be first computed and then, knowing the mix and the materials, the quantities of the various materials may be calculated.

Diagrams 11-6 and 11-7 (pages 623 and 624) show the costs of materials per 100 sq. yd. of surface when the prices of the

materials are known and the quantities required per cubic foot may be reasonably assumed.

TABLE 11-9.—APPROXIMATE QUANTITIES OF MATERIALS REQUIRED PER CUBIC FOOT AND PER CUBIC YARD FOR PLASTER

Kind of plaster	Mix by wt.	Materials	Quantities per cu. ft.	Quantities per cu. yd.
Ordinary lime for scratch and brown coats	1–2	Hydrated lime Hair and fiber Sand	40– 45 lb. 0.07–0.10 bu. 80– 90 lb.	1,100–1,200 lb. 2.0– 2.5 bu. 2,200–2,400 lb.
	1–3	Hydrated lime Hair and fiber Sand	30– 33 lb. 0.07–0.10 bu. 90– 100 lb.	800– 900 lb. 2.0– 2.5 bu. 2,400–2,700 lb.
Gypsum, hard, patent, or prepared for scratch and brown coats	1–2	Plaster cement Sand	40–45 lb. 80–90 lb.	1,100–1,200 lb. 2,200–2,400 lb.
	1–3	Plaster cement Sand	30– 33 lb. 90–100 lb.	800– 900 lb. 2,400–2,700 lb.
White finish......	2–1	Finish hydrated lime Plaster of paris	40–50 lb. 20–25 lb.	1,100–1,350 lb. 550– 700 lb.
Gypsum, sanded..	1–2	Gypsum Sand	40–45 lb. 80–90 lb.	1,100–1,200 lb. 2,200–2,400 lb.
Keene's..........	...	Keene's cement Hydrated lime	40–50 lb. 20–25 lb.	1,100–1,350 lb. 550– 700 lb.
Prepared white finish..........	...	....	60–75 lb.	1,600–2,000 lb.

Exterior Plaster or Stucco.—There are three kinds of exterior plaster or stucco in common use: lime, portland cement, and magnesite. Lime stucco may not prove satisfactory in cold (freezing) climates and magnesite in wet climates.

Lime stucco is a mixture of slaked or hydrated lime, sand, and sometimes other ingredients.

Portland-cement stucco is a mixture of portland cement, a small amount of lime, sand, and perhaps other ingredients such as grit, crystals, or pebbles.

Magnesite stucco is a mixture of a calcined and ground magnesite rock (magnesium oxide), sand, and other ingredients such as asbestos, grit, mineral colors, crystals, or pebbles. The liquid used is magnesium chloride. Magnesite stucco is sold under various trade names such as Kellastone and Rockbound.

Stucco may be applied directly to masonry such as rock, concrete, brick, or tile walls, or it may be applied to metal lath furred out a short distance from the walls. Wood lath is rarely used, except in dry climates, because of the effect of moisture on the volume of the wood.

Lime stucco is usually applied in two or three coats, no coat being less than ¼ in. thick, and the total thickness of the coats being ¾ in. to 1 in. The mixes for the scratch and brown coats may be 1 to 2 or 1 to 3 by weight, and that of the finish coat, 1 to 2 by weight.

Portland cement stucco is usually applied in two or three coats, no coat being less than ¼ in. thick, and the total thickness being about ¾ in. or a little more. The mix for the scratch and brown coats is usually 1 to 2 or 1 to 3 by weights or volume, and 1 to 2 for the finish coat.

Magnesite stucco is usually applied in two coats, each ¼ in. thick. This stucco usually comes with the dry materials ready mixed and in 100- or 200-lb. bags.

TABLE 11-10.—APPROXIMATE QUANTITIES OF MATERIALS REQUIRED PER 100 SQ. YD. FOR A STUCCO COAT ¼ IN. THICK

Kind of stucco	Mix by weight	Materials	Quantity per 100 sq. yd., ¼ in. thick
Hydrated lime	1–2	Lime	800– 900 lb.
		Sand	18 cu. ft., or 1,600–1,800 lb.
	1–3	Lime	600– 670 lb.
		Sand	20 cu. ft., or 1,800–2,000 lb.
Portland cement	1–2	Cement	9–10 sacks, or 900–1,000 lb.
		Lime	80– 100 lb.
		Sand	20 cu. ft., or 1,800–2,000 lb.
	1–3	Cement	6–7 sacks, or 600– 670 lb.
		Lime	60– 90 lb.
		Sand	20 cu. ft., or 1,800–2,000 lb.
Magnesite stucco	...	Dry mixture	20 cu. ft., or 1,500–1,800 lb.

equipment should include transportation to and from the job, depreciation and maintenance on ordinary scaffolding and tools, and costs of special scaffolding, mixers, and hoists if these are used.

TABLE 11-12.—APPROXIMATE LABOR REQUIRED FOR EXTERIOR PLASTERING AND STUCCO ON PLAIN SURFACES

Kind of work	Square yards per hour		Labor-hours per 100 sq. yd.	
	Plasterer	Helper	Plasterer	Helper
Lime stucco, 3 coats:				
Scratch	12–20	12–20	5– 8	5– 8
Brown	11–17	11–17	6– 9	6– 9
Finish	7–12	8–17	8–14	6–12
Portland cement, 3 coats:				
Scratch	10–17	10–17	6–10	6–10
Brown	7–12	7–12	8–14	8–14
Finish	6–12	8–17	8–16	6–12
Magnesite, 2 coats:				
Scratch or base	10–17	10–17	6–10	6–10
Finish	10–17	10–17	6–10	6–10
Special finishes, such as pebble dash, slate or spatter dash, and browned	6– 8	8–11	12–16	9–12

On most building jobs, an allowance of $20 to $25 will usually be sufficient for each gang of about four or five plasterers (or less) and their helpers.

12. Overhead and Profit.—Overhead on plastering jobs is usually based on labor costs and may vary from about 20 to 45 per cent of labor costs, or from 10 to 25 per cent of the cost of labor and materials.

Profit may range from about 5 to 15 per cent of all other costs.

13. Plastering Estimates.—The estimate for the total cost of plastering should include the following:

Materials. Lime, plaster, cement, hair, fiber, sand, etc.

Labor. Plasterers and helpers. Foreman also if the number of workmen warrants.

Equipment. All equipment costs.

Overhead. Based on labor costs or on sum of material and labor costs.

Profit.

The summary or tabulation should show unit costs per square yard of surface (or per 100 sq. yd.) as well as total costs.

14. Illustrative Estimate.—Prepare estimates of the cost of plastering the rooms of the illustrative estimate on lathing estimates (Art. 7 of this chapter), assuming that either wood lath, metal lath, or plaster board may be used.

If on wood lath, ⅜ by 1.5 in., the grounds are ⅞ in. and three coats of plastering are to be used.

If on metal lath, the grounds are ¾ in. and three coats of plastering are to be used.

If on plaster board, ½ in. thick, the grounds are 1 in. and two coats of plaster are to be used.

Plaster mix is 1 to 2 by weight of gypsum plaster and sand for the scratch and brown coats, and for the gypsum sanded finish coat.

Prices of materials delivered at the job are as follows:

Gypsum plaster........	$22 per short ton in 100-lb. sacks.
Sand.................	$2 per short ton.
Water................	$1 proportional charge for the job.

Wages are: Plasterer $1.30 per hour. Helper $0.70 per hour.

Equipment: Allow $20.

Overhead: Allow 27 per cent of labor costs.

Profit: Allow 8 per cent of all other costs.

Solution: From the illustrative estimate on lathing, the net area is 221 sq. yd.

As the mixes for all coats are the same, the amounts required will be about as follows:

Plaster in Cubic Feet per 100 Square Yard

Item	On wood lath	On metal lath	On plaster board
Scratch coat..........................	{14 {10	{20 {10	30
Brown coat ¾ in....................	20	20	
Finish ⅛ in..........................	10	10	10
Total..................................	54	60	40

Materials per cubic foot are 45 lb. gypsum and 90 lb. sand.

Materials for 100 Sq. Yd. of Plaster, Pounds

	On wood lath	On metal lath	On plaster board
Gypsum..........................	2,430	2,700	1,800
Sand..............................	4,860	5,400	3,600

MATERIALS FOR 221 SQ. YD. OF PLASTER, POUNDS

	On wood lath	On metal lath	On plaster board
Gypsum	5,380	5,970	3,980
Sand	10,750	11,930	7,960

EXPRESSED IN TONS

	On wood lath	On metal lath	On plaster board
Gypsum	2.7	3	2
Sand	5.5	6	4

COST (TO NEAREST DOLLAR)

	On wood lath	On metal lath	On plaster board
Gypsum at \$22 per ton	\$59	\$66	\$44
Sand at \$2 per ton	11	12	8
Water	1	1	1
Cost of materials	\$71	\$79	\$53
Cost per square yard	\$0.321	\$0.357	\$0.240

If desired, Diagram 11-6 could be used for finding cost of sand per cubic foot of plaster. This diagram gives a cost of \$0.09 per cubic foot of plaster. Diagram 11-7 gives a cost of \$0.495 per cubic foot of plaster for gypsum. Total cost of sand and gypsum is \$0.585 per cubic foot.

For plaster materials on wood lath, the cost is \$0.585 × 54 × 221 ÷ 100, or \$70 without water.

For plaster materials on metal lath, the cost is \$0.585 × 60 × 221 ÷ 100, or \$78 without water.

For plaster materials on plaster board, the cost is \$0.585 × 40 × 221 ÷ 100, or \$52 without water.

LABOR-HOURS PER 100 SQ. YD.

	On wood lath		On metal lath		On plaster board	
	Plasterer	Helper	Plasterer	Helper	Plasterer	Helper
Scratch coat	6	6	6	6	10	10
Brown coat	10	10	10	10		
Finish coat	11	6	11	6	11	6
Total	27	22	27	22	21	16

LABOR-HOURS AND LABOR-COSTS FOR 221 SQ. YD.

	On wood lath		On metal lath		On plaster board	
	Plasterer	Helper	Plasterer	Helper	Plasterer	Helper
Total hours	60	49	60	49	47	36
Cost	$78	$34	$78	$34	$61	$25
Cost of plasterers and helpers	$112		$112		$86	
Cost per square yard	$0.507		$0.507		$0.389	

If desired, the labor cost per square yard may be taken from Diagram 11-8. For plastering on wood lath, cost of plasterer at $1.30 per hour is $0.351 per square yard and of helper $0.70 per hour is $0.154, or a total labor cost of $0.505 per square yard compared with the computed value of $0.507. The same costs will be found for plastering on metal lath as the labor-hours assumed per square yard were the same as for the wood lath. For plaster board, the labor costs will be $0.273 for the plasterer plus $0.112 for the helper, or a total of $0.385 as compared with $0.389 computed. The difference in values is caused by not using fractions of hours and dollars in the computations.

Cost of equipment is $20 for the job or $0.091 per square yard.

Overhead costs are 28 per cent of labor costs.

Profit is 8 per cent of all other costs.

The plastering estimates may be summarized as follows:

Item	Cost per square yard			Total costs		
	On wood lath	On metal lath	On plaster board	On wood lath	On metal lath	On plaster board
Materials	$0.321	$0.357	$0.240	$ 71	$ 79	$ 53
Labor	0.507	0.507	0.389	112	112	86
Equipment	0.091	0.091	0.091	20	20	20
Overhead	0.145	0.145	0.109	32	32	24
Profit	0.082	0.091	0.068	18	20	15
Total	$1.146	$1.191	$0.897	$253	$263	$198

Perhaps a totaling of the estimated costs of lathing and plastering would be of interest.

	Cost per square yard			Total costs		
	On wood lath	On metal lath	On plaster board	On wood lath	On metal lath	On plaster board
Lathing.........	$0.670	$0.648	$0.868	$148	$143	$192
Plastering.......	1.146	1.191	0.897	253	263	198
Total..	$1.816	$1.839	$1.765	$401	$406	$390

CHAPTER XII

HEATING AND AIR CONDITIONING

A. HEATING AND AIR-CONDITIONING SYSTEMS

1. Estimating of Heating and Air Conditioning.—Detailed estimates of heating and air conditioning are almost always prepared by subcontractors who specialize in this kind of work. The general contractor (or his estimator) rarely has the specialized knowledge required for making accurate and detailed estimates, but he should have a general knowledge of the work so that he can take-off the required materials with reasonable accuracy and prepare approximate estimates of the quantities and costs of materials and labor, and of the costs of equipment, overhead, and profit. These approximate estimates may be used for the purpose of checking and determining the reasonableness of the bids submitted by the subcontractors, or for making approximate estimates of the costs when subcontractors' bids are not available.

Cost estimates of heating and air-conditioning systems will include the five main items of materials, labor, equipment, overhead, and profit. Unit costs may be computed as desired. Some units are cost per outlet in warm-air heating; cost per radiator or the cost per square foot (or 100 sq. ft.) of radiation in steam and hot-water heating; the cost per cubic foot (or 1,000 cu. ft.) in air conditioning; the cost per square foot (or 100 sq. ft.) of floor area; and the cost per cubic foot (or 1,000 cu. ft.) of volume of space heated. Other information should be included, such as size of structure, kind of structure (wood, brick, steel, etc.), occupancy or use (residence, office, school, factory, store, etc.), locality and climate, temperature ranges, and kind of heating plant. Such information is necessary if the costs are to be used for comparative purposes.

In the preparation of an approximate estimate by the contractor (or his estimator), it is assumed that the plans and specifications furnished him are complete enough so that no designing is

necessary and also that enough information is given so that all materials required can be readily taken off. On many of the larger jobs, special heating plans and drawings are provided. Many of the heating details are shown on the plans by symbols. Hence, the contractor must have a knowledge of the meanings of these various symbols.

There are so many types and combinations of heating and air-conditioning systems that it is not practical to try to include all of them in one chapter. The estimating of only a few of the more common types will be discussed.

2. Heating Systems.—The main purpose of a heating system is to provide and maintain temperatures. There are many types of heating plants in use. Some are simple, others are complex. Some use but one method of heating, others combine two or more methods. Some are combined with air-conditioning systems, others are not.

The following classifications illustrate several ways of classifying heating systems:

Type..............	Fireplace. Stove. Warm-air furnace. Steam. Hot water.
Kind of radiation...	Direct. Indirect. Combinations.
Heat flow..........	Radiation. Conduction. Convection.
Piping.............	Single- or two-pipe systems. Wet or dry returns. Upfeed from basement or downfeed from attic.

The classification as to type is believed to be the best for use in general estimating purposes.

A. Warm-air heating systems.
- Pipeless system.
- Ordinary pipe system.
- Ordinary pipe system with auxiliary fan.
- Pipe system with mechanically operated fan.
- The first three are usually called *gravity* systems, and the fourth is a *pressure* or *forced-air* system.

B. Steam-heating systems.
- Pressure. One- or two-pipe system.
- Vapor. Very low pressure. One- or two-pipe system.
- Vacuum. With vacuum pump. Two-pipe system.
- Zone control. Pressure system with different pipe lines independently controlled.

The single-pipe pressure or vapor system is often used for residences, small stores, and small industrial buildings.

The overhead single-pipe pressure system or the vacuum system is often used for large industrial buildings.

The vacuum system is preferred for all other large, well-furnished buildings, such as large office buildings.

C. Hot-water heating systems. Two-pipe system.
   Gravity. Open and closed types.
   Pressure. Closed type.
   Forced. Pumps used to force water through system.
   Flow control. Boiler maintained at definite temperature. One pump and controls for each independent piping circuit.

The selection and design of a heating system often includes the following:

1. Selection of system. Consideration is given to kind and size of structure, occupancy, first cost, probable life, maintenance and repairs, operating costs, kind of fuel to be used, firing system, climate and temperature variations, and desires of architect and owner.

2. Computation of heat losses. Heat losses are computed for each room and for the building.

3. Design of distribution units. Registers or radiators.

4. Design of conveying system. Air pipes, steam and water pipes, etc.

5. Selection of heat-generating unit (furnace or boiler) and of fuel-firing system (stoker, oil burner, gas burner).

6. Selection of accessories, other than those included with 3, 4, and 5.

7. Selection of heat-control system.

The take-off for estimating purposes includes the following main headings with as many subheadings as desired.

1. Heat-distributing units.
2. Heat-conveying system.
3. Heat-generating units.
4. Accessories.
5. Heat-control system.

3. Air-conditioning Systems.—Complete air conditioning may be said to include control of temperature, humidity, air supply,

air motion, air distribution, dust, bacteria, odors, and gases. These items may be arranged in three groups:

Ventilation. Air supply and distribution.

Comfortable temperature. Temperature, humidity, and air motion.

Purification. Dust, bacteria, odors, toxic gases, and other injurious substances.

The following list will give an idea of the various kinds of air-conditioning systems in use:

Gravity systems. Windows, vent ducts, roof ventilators.

Mechanical systems. Separate or combined with heating system. Central and unit systems.

The various mechanical central systems include:

Ventilation by fan. All of heat by direct radiation (Split system).

Ventilation and part of heat by fan. Remainder of heat by direct radiation.

Ventilation and all of heat by fan. (Hot-blast system.)

Heat by radiation. No fan.

Heat by fan. No ventilation.

Fan furnace system.

Plus humidifiers, filters, washers, etc., as desired.

The mechanical unit systems include:

Unit heaters. These consist of a fan and heater enclosed in a box or case. Their purpose is to recirculate and warm the air in the room. They may include a humidifier. Steam is usually used for heating.

Unit coolers. These consist of a fan and a cooler enclosed in a case. They may include a dehumidifier. Their purpose is to recirculate and cool the air in the room. Cold water is often used as a cooling agent.

Unit conditioners (ventilators). These consist of a fan and filter mounted in a casing. A humidifier may be added. All or part of the air may be taken from the outside.

Unit conditioners (heaters). Similar to the unit ventilators with a method added for heating the air. Steam coils are used for heating.

Unit conditioners (coolers). Similar to the unit ventilators with a cooler and dehumidifier added. The cooling agent may be cool water or a refrigerating unit.

The unit system may be placed on the floor, suspended from the ceiling, or attached to the wall.

The central system was formerly used in nearly all kinds of large buildings. At the present time, the unit system is becoming popular in several kinds of buildings.

Formerly, air conditioning often included air supply, air distribution, air motion, heating, and humidifying. At the present time, many systems include filters or washers for purifying the air. Cooling may be accomplished by using a supply of cooler air, cold water, or refrigerating units.

The selection and design of an air-conditioning system will include the following:

1. Selection of system. Consideration given to kind, size, and occupancy of building and results to be obtained.

2. Computation of various kinds of work to be done. Air quantities, air velocities, heating, cooling, filtering or washing, etc.

3. Selection of apparatus and partial design as required.

4. Selection of a suitable controlling system.

The take-off for a central system should include a list of the various outlets, ducts, motors, fans, heaters, coolers, humidifiers, washers, filters, etc., required with their accessories and control devices.

The take-off for a unit system should include a list of all the individual units required with information as to size, location, connections, and other details, plus accessories and control devices.

When the air-conditioning system is combined with a heating system, then two systems are often taken off and estimated together. If the air-conditioning and heating systems in a combined system are taken off and estimated separately, the estimator must be very careful to include all items required for each system, and at the same time he must also be careful to avoid duplications.

B. STEAM AND HOT-WATER HEATING SYSTEMS

4. Materials Take-off.—Before the take-off of the materials can be made, the estimator should have available a fairly complete set of heating plans showing the location of the boiler, the arrangement of the horizontal piping in the basement, the

arrangement of all vertical piping, the location of all radiators, and all necessary details in regard to makes, kinds, sizes, etc., of all items required. Detailed specifications should accompany the plans, giving all additional information needed.

Sometimes no detailed plans of the heating system are provided. When such is the case, the general contractor may ask competent subcontractors for bids accompanied by sketches showing the layout of the heating system. Or the general contractor may have a competent heating engineer design the heating system and prepare sets of plans and specifications, and give a set to each subcontractor who is to bid on the job. Then the general contractor may use one of these sets of plans for checking the bids received.

Perhaps the best way of taking off the required materials is to go over the plans in detail and list all materials under the five main headings, using as many subheadings and remarks as necessary. Some estimators prefer to go over the plans floor by floor and list all materials on each floor before proceeding to another floor. Other estimators prefer to go over the plans and list all heat-distributing units, and then repeat the process for pipes, etc. A good idea is to check each item on the plans as it is listed, using a red or other colored pencil. Many estimators prefer to use ruled sheets, sometimes with the various items printed cn them, for the take-off. A reminder list is helpful. Such a list is given in Appendix A. If the job is fairly large, a summary sheet should be used.

The take-off should include the following:

1. Heat-distributing units. Radiators, valves, air valves, etc., with notes as to sizes, heating surface, height, etc. These may be taken off floor by floor and then summarized.

2. Heat-conveying system or piping. All pipes, valves, joints, tees, elbows, unions, traps, tanks, etc., should be listed with details as to sizes, etc., starting at the furnace or boiler and working around each circuit in order.

3. Heat-generating units. Boiler, stoker, burner, etc., with smoke pipe, dampers, valves, gages, etc., such as usually accompany and are attached to these units.

4. Accessories. Various items not usually included with radiators, pipes, boilers, and heat controls. Some of these items may be extra tanks, traps, pumps, valves, etc. An estimator

must use his own judgment in regard to classifying certain items as accessories or as parts of the boiler or piping system.

5. Heat-control system. All thermostats, wiring, transformers, piping, pressure-stats, rheostats, cutouts, and various other items included in the particular system selected.

5. **Materials. Heat-distributing Units.**—The *materials* usually included are radiators, air valves, valves, unions, reducers, covers, hangers, and fans as required. Some estimators include radiator valves, unions, reducers, etc., with the piping system. Radiators are usually made of cast iron, but may be of other materials. They are of the tube type, may be mounted on floor or wall, may be concealed, may have covers and enclosures, and may have fans.

TABLE 12-1.—SQUARE FEET OF HEATING SURFACE PER SECTION OF CAST-IRON TUBE FLOOR RADIATORS

Height from floor, in.	Number of tubes				
	3	4	5	6	7
	Heating surface per section, sq. ft.				
14	.....	......	....	......	2.50
17	.....	......	....	......	3.00
20	1.75	2.25	2.67	3.00	3.67
23	2.00	2.50	3.00	3.50	4.25
26	2.33	2.75	3.50	4.00	5.00
32	3.00	3.50	4.33	5.00	
38	3.50	4.25	5.00	6.00	
Width, in.	4.625	6.3125	8.00	9.6875	11.375

Radiators are usually listed as to type, height, number of tubes, number of sections, heating surface in square feet per section and per radiator. Hot-water radiators are invariably larger than steam radiators. An average cast-iron radiator may be assumed to have a heat emission of about 240 B.t.u. per square foot per hour with steam, and about 160 B.t.u. per square foot per hour for hot water. Hence, the heating surface of a hot-water radiator should be approximately 1.5 times that of a corresponding steam radiator. Cast-iron radiators are often priced per section with height, number of tubes, and square feet

of heating surface given. However, the price per square foot of heating surface is practically the same for all sections. This price (1946) may range from about \$0.25 to \$0.40 per square foot of heating surface. Hence, the estimator may find the total square feet of heating surface for all radiators and use a suitable price per square foot. Dealers' catalogues should be consulted for information concerning sizes and square feet of heating surface.

Table 12-1 gives some information regarding cast-iron radiators. Average length of section is 2.5 in.

Air valves come in many varieties. For average room radiators, simple air valves may range from \$0.50 and up. About \$0.75 to \$1 is a fair average value. Air valves suitable for use on a vacuum system may cost \$1 and up. About \$1.50 to \$2 is a fair average value.

Table 12-2 gives approximate prices for various radiator fittings.

TABLE 12-2.—APPROXIMATE PRICES OF VARIOUS RADIATOR FITTINGS

Item	Size, inches				
	½	¾	1	1¼	1½
	Cost				
Valves	\$1.00	\$1.20	\$1.50	\$1.90	\$2.30
Floor and ceiling plates	0.05	0.06	0.07	0.08	0.09
Brass union elbows	0.50	0.60	0.75	0.95	1.30
Unions	0.30	0.40	0.50	0.60	0.75
Reducers and bushings	0.06	0.09	0.12	0.15	0.18

Radiator wall hangers may cost \$1 to \$2 per radiator.

Humidifiers to place on radiators may each cost about \$0.50 and up.

Radiator covers may each cost \$1 and up.

Combined radiator covers and humidifiers may each cost \$2 and up.

6. Materials. Piping Systems.—The pipe usually used for steam and hot-water piping systems may be of black or galvanized finish and made of wrought iron or open-hearth or copper-bearing steel. The weight may be nominal or standard, extra strong,

or double extra strong. Copper-bearing steel pipe is preferred because of its ability to resist rust.

The base price for pipe is $200 per net ton f.o.b. mill with various discounts, depending upon kind of finish (black or galvanized), kind of pipe (wrought iron, open-hearth or copper-bearing steel), and nominal diameter of pipe.

Approximate 1946 discounts are as follows:

TABLE 12-3.—APPROXIMATE DISCOUNTS IN PERCENTAGES OF BASE PRICE

Finish	Wrought iron	Wrought steel	Copper-bearing steel
Black...............	25–35	55–65	50–60
Galvanized...........	12–17	45–55	40–50

The list price per foot is found by using the base price of $200 per net ton f.o.b. mill and the weights per foot of length for the different pipe diameters. Net prices are list prices less discounts. Freight, trucking, and handling prices must be added to net prices f.o.b. mill.

Table 12-4 gives information concerning pipes of different sizes. The values given are for black finish. Galvanized pipes will be a little heavier.

Pipe prices in most localities will be appreciably less than list price. Pipe is often purchased per 100 ft. of length. Lengths of individual pieces will vary somewhat, with an average length of about 20 ft. Pipe may come with plain ends, or with threaded ends. Frequently, one coupling is included with each length of pipe. Table 12-5 gives approximate 1946 local prices of steel pipe in percentages of list prices.

Table 12-6 gives approximate 1946 local prices for pipe fittings of standard-weight black pipe.

Pipe larger than 3 or 4 in. is usually designed with flanged fittings. Flanges may be screwed or welded to the pipe. The joint is made by inserting a gasket between the flanges and bolting them together.

Fusion-welded joints are sometimes used for pipe larger than 3 or 4 in.

Brass pipe and fittings may be used. The pipe should be of the standard commercial iron-pipe-gage thickness for the

TABLE 12-4.—SIZES, DIAMETERS, WEIGHTS, AND APPROXIMATE LIST PRICES OF STEEL AND WROUGHT-IRON PIPES

Size, in.	External diameter, in.	Internal diameter, in.			Weights per foot, lb., plain ends			List price per foot		
		Standard	Extra strong	Double extra	Standard	Extra strong	Double extra	Standard	Extra strong	Double extra
0.125	0.405	0.269	0.215	.....	0.244	0.314	......	$0.025	$0.032	
0.250	0.540	0.364	0.302	.....	0.424	0.535	......	0.043	0.054	
0.375	0.675	0.493	0.423	.....	0.567	0.738	......	0.057	0.075	
0.500	0.840	0.622	0.546	0.252	0.850	1.087	1.714	0.085	0.110	$0.175
0.75	1.050	0.824	0.742	0.434	1.130	1.473	2.440	0.115	0.150	0.245
1.00	1.315	1.049	0.957	0.599	1.678	2.171	3.659	0.170	0.220	0.370
1.25	1.660	1.380	1.278	0.896	2.272	2.996	5.214	0.230	0.305	0.525
1.50	1.900	1.610	1.500	1.100	2.717	3.631	6.408	0.275	0.370	0.655
2.0	2.375	2.067	1.939	1.503	3.652	5.022	9.029	0.370	0.510	0.91
2.5	2.875	2.469	2.323	1.771	5.793	7.661	13.695	0.585	0.775	1.39
3.0	3.500	3.068	2.900	2.300	7.575	10.252	18.583	0.765	1.035	1.88
3.5	4.000	3.548	3.364	2.728	9.109	12.505	22.850	0.920	1.265	2.52
4	4.500	4.026	3.826	3.152	10.790	14.983	27.541	1.09	1.52	2.78
5	5.563	5.047	4.813	4.063	14.617	20.778	38.552	1.48	2.10	3.90
6	6.625	6.065	5.761	4.897	18.974	28.573	53.160	1.92	2.89	5.37
8*	8.625	8.071	......	.....	24.696					
8	8.625	7.981	7.625	6.875	28.554	43.388	72.424	2.50	4.39	7.32
10*	10.75	10.192	......	.....	31.201	......	......	3.15		
10*	10.75	10.136	......	.....	34.240	......	......	3.46		
10	10.75	10.020	9.750	.....	40.483	54.735	......	4.09	5.53	
12*	12.75	12.090	......	.....	43.773	......	......	4.42		
12	12.75	12.000	11.750	.....	49.562	65.415	......	5.00	6.61	

* Special sizes furnished when specified with weights given.

Weights are for black finish. Galvanized finish will weigh slightly more. Permissible variation in weight is 5 per cent, more or less.

TABLE 12-5.—APPROXIMATE 1946 LOCAL PRICES OF STEEL PIPE IN PERCENTAGES OF LIST PRICE

Finish	Open-hearth steel		Copper-bearing steel	
	Less than 1 in.	1 in. or larger	Less than 1 in.	1 in. or larger
Black................	50–60	45–55	55–65	50–60
Galvanized...........	60–75	55–65	70–85	60–75

various diameters. Fittings should have thicknesses equal to those of brass pipes of the same diameter. Brass tubing should have a thickness equal to or more than No. 18 gage.

TABLE 12-6.—APPROXIMATE COST OF FITTINGS FOR STANDARD-WEIGHT STEEL PIPE

Size of pipe, inches	Plugs and bushings	Nipples and caps	Couplings, T's, and elbows	Unions
½ or less....	$0.04	$0.05	$0.08	$0.20
1........	0.08	0.07	0.14	0.40
1.5..........	0.12	0.11	0.23	0.65
2............	0.16	0.16	0.38	0.95
2.5..........	0.24	0.25	0.52	1.30
3............	0.30	0.35	0.70	1.60
4............	0.40	0.50	1.00	2.00

Cost of galvanized finish will be about 20 to 25 per cent more than for black finish.

Cost of fittings for copper-bearing steel will be about 10 to 20 per cent more than for open-hearth steel.

Copper tubing, either in straight lengths or in 60-ft. coils, and fittings are available in various diameters up to about 1.5 in. in size. Copper tubing of the smaller diameters may be readily bent around joists, corners, etc., thus saving many fittings and considerable labor. Weights and prices (1946) for copper tubing and prices of fittings are about as shown in Table 12-7 and Table 12-8.

Pipe hangers are required for supporting horizontal pipes. The cost of the hanger will vary with the type and size. Prices may range from about $0.15 to $1 for each.

Pipe covering or pipe insulation may be composed of such materials as magnesia, asbestos, mineral wool, and combinations. A suitable, though not always long lasting, covering is made of asbestos in combination with a cellular material. Prices vary with material, thickness, and size of pipe.

Shutoff valves should preferably be provided for each circuit so that the entire plant may not need to be shut down in order to repair one line. Prices of valves will depend upon kind, quality, and make. Prices may range from about $1 or more for a 1-in. valve to about $3 or more for a 2-in. valve, $6 or so for a

3-in. valve, \$10 or more for a 4-in. valve, and more for the larger sizes.

TABLE 12-7.—APPROXIMATE WEIGHTS AND PRICES OF COPPER TUBING

Tube diam., in.	Weight per 100 ft., lb.		Price per 100 ft.	
	Standard	Heavy	Standard	Heavy
3/8	23.5	28	\$ 75	\$ 95
1/2	30	37.5	105	120
3/4	50	69	150	200

TABLE 12-8.—APPROXIMATE PRICES OF FITTINGS FOR COPPER TUBING

Tube diam., in.	T's	Union elbows	Elbows	Unions	Adapters	Flaring tools	Radiator valves
3/8	\$0.45	\$0.90	\$0.35	\$0.30	\$0.25	\$0.25	\$2.50
1/2	0.60	1.00	0.50	0.40	0.30	0.30	2.75
3/4	0.75	1.15	0.65	0.55	0.35	0.40	3.25

Reducing valves, steam traps, steam separators, and other items may be required on some systems.

The estimator should refer to dealers' catalogues and price lists when preparing estimates of piping and pipe fittings and accessories. Prices vary according to time and place. Prices given in this chapter are approximate only, and should not be used except for very approximate estimates.

7. Materials. Boilers and Accessories.—The boiler selected should be of the proper kind for the fuel used and of sufficient size to do the work. There are many types of boilers used for heating work, the more common being the cast-iron boiler, the steel fire-tube boiler, and the steel water-tube boiler.

Heating boilers are rated according to the number of square feet of radiation they can handle.

The design of the boiler will also vary according to the fuel and method of firing. With coal, boilers may be hand or stoker fired. Oil burners are used for oil fuel, and gas burners for gas.

Round cast-iron boilers, consisting of three to five main castings, may be obtained in capacities up to about 1,600 sq. ft. of radiation.

Sectional cast-iron boilers, consisting of 5 to 10 sections, may be obtained in capacities up to about 18,000 sq. ft. of radiation.

Steel boilers may be riveted or welded. The fire-tube type may be used in capacities up to about 15,000 sq. ft. of radiation, and water-tube boilers for larger capacities.

The boiler selected must be large enough to provide the heat required:

1. By all radiators with normal room temperature and minimum outside temperature.
2. For all heat losses by the piping system.
3. By all attached water heaters.
4. For bringing all room temperatures from a lower temperature up to the desired temperature during the warming up time.
5. For raising the temperature of the metal in the system to the requisite working temperature.

Items 1, 2, and 3 make up the design load; and items 4 and 5, the starting load.

Heat requirements are approximately as follows:

240 B.t.u. per hour per square foot of steam radiation.

160 B.t.u. per hour per square foot of hot-water radiation.

2 B.t.u. per hour per square foot of uncovered pipes.

0.5 to 1 B.t.u. per hour per square foot, of insulated (covered) pipes.

TABLE 12-9.—APPROXIMATE BOILER COSTS PER 100 SQ. FT. OF RADIATION

Boiler	Radiation, square feet					
	300	600	1,000	1,500	2,000	3,000
	Cost per 100 sq. ft. of radiation					
Hot water.......	$20	$17	$15	$14	$13	$12
Steam..........	32	27	23	21	20	19

The maximum load that a boiler will be expected to carry will be the sum of the design and starting load. The starting load may vary from about 65 to 50 per cent of the design load for design loads varying from almost nothing up to 1,200,000 B.t.u. per hour.

Prices of boilers will vary according to kind, make, and capacity. Approximate prices for 1946 are about as given in Table 12-9 for boilers without accessories except pet cocks, water glass, gage, safety valve, and damper for steam boilers and pet cocks, thermometer, and damper for hot-water boilers.

Coal stokers for boilers with capacities up to 3,000 sq. ft. of radiation may range in price from about $150 to $600, depending on make and size.

An oil burner with tank and accessories may cost $150 to $600.

Combined boilers and oil burners will cost about the same as when the boiler and burners are considered separately. Special designs may be more expensive.

Combined boilers and gas burners will cost about the same as boilers with oil burners or stokers. Special designs will cost more.

Other accessories with hot-water boilers may be expansion tanks, valves, circulating pumps, hot-water heaters, boiler feed pumps, etc.

Other accessories with steam boilers may be valves, air or vent valves, special returns, safety valves, hot-water heaters, traps, low-water cutouts, vacuum pumps, boiler feed pumps, etc.

Prices of various accessories may be obtained from local dealers, out-of-town dealers, and various catalogues.

8. Materials. Temperature Controls.—There are various types of temperature-control systems in use. They may be classified as follows:

Central Thermostat.—A central thermostat, supplemented by pressure control for steam heat, and by temperature control for hot-water and warm-air heat, is almost the standard type for residences and other small buildings.

Individual Room Thermostats.—Individual room thermostats may be of the compressed-air, electrical, or self-contained radiator valve type. The compressed-air and electrical types are often used in public buildings. These types are comparatively expensive to install and maintain.

Central Control.—Central control with radiator orifices, variation in steam pressure, variation in hot-water temperatures, or with a varying supply are sometimes used in large buildings to give an approximate temperature control and to save fuel.

Zone Control.—Approximate temperature control by a zone or circuit system results in some economy in fuel consumption.

This system may be used advantageously in combination with other types of control.

The cost of a temperature-control system will vary with the type of system and make. A central-thermostat system may cost \$40 to \$100 plus installation. An individual room-thermostat system may cost \$10 or \$15 and up per room. The cost of a central-control system will vary greatly with the type and make selected and the number of radiators, etc., to be controlled. With the zone system used in combination with a thermostat system, the cost for each zone may vary from about \$40 to \$100 plus the cost of extra pumps, valves, checks, etc., as required.

9. Labor.—The installing of steam and hot-water heating systems is usually done by teamwork. For ordinary work, the team may consist of one steam fitter and one helper. On heavy work, the team may consist of one steam fitter and two or more helpers, or two or more two men teams may be used. On large jobs, there may be several teams working at the same time under the direction of a foreman or superintendent.

The time required for doing a certain item of steam- or hot-water-heating work will vary considerably, depending upon the particular work, the working conditions, and the skill and inclination of the workmen.

The time required for installing radiators may be estimated per radiator.

Labor for pipe work may be more accurately estimated per joint instead of per 100 lin. ft., with kind of pipe and diameter given. The labor per joint will include all threading, hanging, and connecting needed. It is assumed that an adequate supply of nipples, couplings, unions, and other fittings is available. The larger the pipe, the more labor-hours required. When estimating threaded joints, each coupling, valve, or union counts as two joints, and a T as three joints, etc.

For pipe up to 3 or 4 in. in size, a team of 1 pipe fitter and 1 helper is satisfactory; for pipe sizes of 4 to 6 in., the team should be composed of 1 pipe fitter and 2 helpers. For pipe sizes from 6 to 12 in., a team of 1 pipe fitter and 3 helpers may be required. For pipe sizes of 14 to 24 in., a team of 1 or 2 pipe fitters and 3 to 5 helpers may be needed. The labor-hours given for pipework in Table 12-10 are based on the assumption that one pipe thread must be cut for each joint. When it is not neces-

sary to cut a thread, the time given may be reduced 35 to 50 per cent.

Furnaces, fittings, and accessories are usually installed by gangs of two or more men, depending upon the weights to be handled. An electrician will be needed if any electrical work is required.

Temperature-control systems are usually installed by a man or men skilled in this work, assisted by helpers. The skilled workmen may be pipe fitters or electricians or both, depending upon the kind of system to be installed.

Table 12-10 gives approximate labor-hours required for various items of work in connection with the installation of steam and hot-water systems.

The wages of pipe fitters, electricians, and other skilled labor may vary from about $1.25 to $2.25 per hour, with average values between $1 and $2. Wages of helpers may vary from about $0.65 to $1.25 per hour, and in any locality are approximately equal to about half the skilled laborer's wage.

Diagrams 12-1 and 12-2 (pages 626 and 627) may be used for estimating the labor cost of installing pipe work and other items when the labor wage is known and the time required may be reasonably assumed.

10. Equipment.—The equipment needed will vary somewhat with the character and size of the job. Each team of pipe fitter and helpers may need pipe cutters, pipe threaders, vise and vise frame, wrenches, hammers, chisels, and other small tools. If an electrician is required, he will need his set of tools. Sometimes ladders, sawhorses, plank, etc., are also needed.

The cost of a set of tools for one team will be comparatively little for any one job. Transportation costs to and from the job should be included. The equipment cost will vary with the size of the job and the length of time required. Equipment costs per team per job may range from about $5 or $10 to $25 or $30.

11. Overhead and Profit.—Overhead may be based on labor costs alone or on the sum of materials, labor, and equipment. Overhead costs should include all general overhead items plus compensation and other insurance, social security taxes, and costs of all fees and permits.

General overhead costs may range from 15 to 35 per cent of the labor costs plus about 2 to 7 per cent for compensation insurance

TABLE 12-10.—APPROXIMATE LABOR-HOURS REQUIRED FOR INSTALLING STEAM AND HOT-WATER HEATING SYSTEMS

Item	Labor-hours	Item	Labor-hours
Radiators, one-pipe system, including steam and air valves:		Boiler, small, 600 sq. ft. steam radiation or less	8–16
Floor	1.4– 2.0	Medium, 600 to 1,000 sq. ft. steam radiation	12–24
Wall	1.7– 2.5	Large, over 1,000 sq. ft. steam radiation per 1,000 sq. ft. radiation	10–20
Radiators, two-pipe system, including steam and air valves:		Coal stoker, small	4– 8
Floor	2.0– 3.0	Large	6–20
Wall	2.4– 3.5	Oil burner and tanks, small	4–10
Pipe work, per joint:		Large	6–20
Threaded, ½ in. and smaller	0.3– 0.5	Valves, each	0.5– 1
Threaded, ¾ and 1 in.	0.4– 0.6	Traps, each	5–15
Threaded, 1¼ and 1½ in.	0.5– 0.8	Tanks, each	2–10
Threaded, 2 and 2½ in.	0.7– 1.1	Pumps, each	5–20
Threaded, 3 and 3½ in.	0.9– 1.6	Temperature control:	
Threaded, 4 in.	1.3– 2.0	Central thermostat	3– 6
Threaded, 5 in.	2.0– 3.0	Room thermostats, each room	2– 4
Threaded, 6 in.	2.5– 4.0	Central control, variable	3–12
Flanged, 4 in.	1.4– 2.2	Zone system, each zone	3– 6
Flanged, 5 in.	2.0– 3.0		
Flanged, 6 in.	2.5– 4.0		
Flanged, 8 in.	3.5– 5.0		
Flanged, 10 in.	5.0– 6.5		
Flanged, 12 in.	6.5– 8.5		
Flanged, 14 in.	8.0–10.0		
Flanged, 16 in.	10.0–12.0		
Flanged, 20 in.	13.0–17.0		
Flanged, 24 in.	15.0–20.0		
Asbestos pipe covering for pipe in 3 ft. lengths:			
¾ in. and less, per 100 ft.	2.0– 3.0		
1, 1¼, and 1½ in. per 100 ft.	2.5– 3.5		
2 and 2½ in. per 100 ft.	3.0– 4.0		
3 and 3½ in. per 100 ft.	3.5– 4.5		
4 and 5 in. per 100 ft.	4.0– 5.0		
6 in. per 100 ft.	4.5– 5.5		
8 in. per 100 ft.	5.0– 6.0		
10 in. per 100 ft.	6.0– 7.5		
12 in. per 100 ft.	7.0– 9.0		

9 elbows, 2 reducers for 1.5-in. pipe.
37 elbows and couplings for 1.25-in. pipe.
84-ft. asbestos pipe insulation for 2-in. pipe.
92-ft. asbestos pipe insulation for 1.5-in. pipe.
1 thermostat complete (to be selected by owner).

Material price estimates may be obtained from local wholesaler, or from catalogues with allowance for freight and trucking.

A gang of 2 pipe fitters and 2 helpers (two 2-men teams) will be used. Wages are $2 per hour for pipe fitters and $1 for helpers.

Assume a reasonable cost of equipment.

Contractor's overhead costs to be assumed as 30 per cent of labor cost, including all general overhead, compensation insurance, social security tax, etc.

Assume profit at 10 per cent of all other costs.

Materials cost (to nearest dollar). Prices are costs (without profit) of materials delivered at the job.

			Local Prices
1 steam boiler, capacity 550 sq. ft. of radiation, with jacket and trim		=	$136
1 stoker		=	148
15 radiators, 169 sections, 507 sq. ft.	at $0.29	=	147
15 air valves for radiators	at $0.85	=	13
2 large air valves	at $4.50	=	9
15 radiator valves	at $2.00	=	30
15 radiator unions	at $0.50	=	8
15 floor plates	at $0.10	=	2
15 bushings	at $0.10	=	2
84 ft. 2-in. copper-bearing steel pipe	at $0.22	=	19
14 T's, 2 reducers, 7 elbows	at $0.35	=	8
92 ft. 1½-in. copper-bearing steel pipe	at $0.17	=	16
9 elbows, 2 reducers	at $0.25	=	2
145 ft. 1¼-in. copper-bearing steel pipe	at $0.15	=	22
37 elbows and couplings	at $0.20	=	8
176 ft. asbestos covering for 2-in. and 1½-in. pipe	at 0.11	=	19
1 thermostat complete (as selected by owner)		=	60
Total		=	$649

Labor cost (2 pipe fitters at $2 per hour and 2 helpers at $1 per hour, average wage of $1.50 per hour):

1 steam boiler and trim	12 labor-hours
1 stoker	6 labor-hours
15 radiators	25 labor-hours
2-in. pipe equivalent of (42 + 4 + 14) or 58 joints	47 labor-hours
1.5-in. pipe equivalent of (18 + 4) or 22 joints	16 labor-hours
1.25-in. pipe equivalent of 74 joints	45 labor-hours
176 ft. of asbestos covering	6 labor-hours
1 thermostat	5 labor-hours
Total (81 team-hours)	162 labor-hours

Labor cost, 162 hr. at $1.50	= $ 243
Equipment cost:	
For 2 teams of 1 pipe fitter and 1 helper each	= 15
Overhead cost:	
Assume 30 per cent of labor cost ($243)	= 73
Profit:	
Assume 10 per cent of all other costs ($980)	= 98
Total estimated cost	= $1,078

This estimate may be summarized as follows:

Item	Unit Cost per Sq. Ft. of Radiation	Unit Cost per Radiator	Total Cost
Materials	$1.28	$43.30	$ 649
Labor	0.48	16.20	243
Equipment	0.03	1.00	15
Overhead	0.15	4.95	73
Profit	0.19	6.55	98
Total	$2.13	$72.00	$1,078

C. WARM-AIR HEATING SYSTEMS

14. Warm-air Heating Systems.—Warm-air heating systems may be classified as follows:

1. Pipeless. Furnace with short warm-air stack to floor above, with cold-air return from floor above. May have a humidifier.

2. Pipe. Furnace with ducts or pipes leading from furnace to warm-air room registers, usually one to a room. Cold-air ducts may lead from one or more rooms or from outside. Furnace usually has a humidifier. May have a thermostat. May have some sort of air-conditioning equipment connected to furnace.

3. Pipe with auxiliary fan. Same as a pipe furnace with a propellor-type fan usually placed in the cold-air duct at furnace. Fan gives better circulation. System usually has a humidifier and electrical controls for fan and may have a thermostat. May also have air-conditioning equipment connected with furnace.

4. Pipe with mechanically operated fan. System has smaller ducts or pipes than the pipe system has. Has a cold-air return for each room or for each set of connected rooms. Fan is usually of centrifugal type. System usually has a humidifier, thermostat, and air-conditioning equipment.

The pipeless and pipe systems are called *gravity* systems. The pipe system with auxiliary fan is a *gravity* system with a fan.

The pipe system with a mechanically operated fan is a *pressure* or *forced-air* system.

The cost estimate of a warm-air heating system will include the five main items of materials, labor, equipment, overhead, and profit. Unit cost may be computed, if desired, per warm-air outlet, per outlet (sum of warm- and cold-air outlets), per square foot of heated floor area, and per cubic foot of heated space.

Warm-air heating systems are frequently used in buildings up to three stories in height and up to 50,000 cu. ft. in volume.

15. Materials Take-off.—It is assumed that the estimator has a fairly complete set of plans and specifications at his disposal so that he may readily take-off and list all the required materials. The use of a good reminder list is advisable.

The take-off may be divided into the following main headings:

1. Heat distribution. Registers and outlets. List size, finish, and other details.

2. Heat-conveying system. Pipes and ducts. List size, shape (round or rectangular), length, elbows and bends, junctions, outlet boxes, dampers, etc., for all warm- and cold-air ducts. Kind (tin or galvanized iron) and gage of metal should be stated. Pipe covering or insulation should be listed when required.

3. Heat-generating system. Furnace with smoke pipe, damper, jacket, and trim. Size, grate area or firebox diameter, and heating capacity should be stated. Note if humidifier, fan, and air-conditioning equipment is included with furnace. Also note kind of fuel such as coal, oil, or gas, and firing equipment. Such equipment is usually listed under accessories.

4. Accessories. Humidifier, fans, blowers, filters, washers, and other air-conditioning equipment if not included with furnace. Coal stoker, oil burner, or gas burner if separate from furnace. Miscellaneous accessories.

5. Temperature controls. Thermostat and other controls, with all needed transformers, wiring, piping, etc.

16. Materials.—Registers (warm-air outlets and cold-air inlets) vary in price according to size, material finish, etc. Prices may range from about \$1.50 for an 8- by 10-in. black japanned floor register up to \$5 for a 12- by 16-in. size. Nickel- or chrome-plated finishes cost more. Cost per square foot may range from \$3 to \$5 for black japanned finish, and from \$4 to \$10 for plated

Humidifiers of various kinds are on the market. The simpler kind may cost about $5 to $25.

A suitable fan for a gravity system may cost $10 to $50.

A coal stoker may cost $125 to $450, depending on size and make, plus installation costs.

An oil burner with tanks and accessories may cost $150 to $450 plus installation costs.

A good thermostat with accessories may cost about $30 to $125.

An air conditioner consisting of a blower (fan and motor), humidifier, and filters (or air washer) may cost about $60 to $300. Such a unit may be attached to a gravity-system furnace.

Warm-air furnaces combined with air-conditioning units and stokers or burners are available in various combinations. A warm-air furnace (mechanical-fan type) of the pressure or forced-air type is usually combined with an air-conditioning unit. The combination will cost about twice as much as a gravity-type furnace of the same capacity, or as much as the sum of the costs of a gravity-type furnace plus an air-conditioning unit.

The prices given for furnaces, stokers, burners, fans, air-conditiong units, etc., are approximate 1946 prices for equipment for ordinary buildings up to about 50,000 cu. ft. in volume.

17. Labor.—The labor required for a warm-air heating system is for the installation of the pipes, registers, furnaces, accessories, and controls. This labor may be done by skilled mechanics or by skilled mechanics aided by helpers.

The labor required for any particular installation may vary considerably according to the kind of job (large or small, new or old building, long or short leaders and stacks, number of bends and turns in pipes, number and kind of accessories, etc.), the working conditions, and the skill and inclination of the workmen. A team composed of a skilled workman with one or two helpers is a good working combination.

Approximate labor-hours required for different items of work are given in Table 12-13. The metal warm- and cold-air pipes and register boxes are assumed delivered at the job made up in correct sizes of junctions, elbows, bends, outlet boxes, and straight lengths of pipe and ready for installation. Labor-hours given for installing furnace includes time for installing jacket, smoke pipe, and damper.

Diagram 12-3 (page 628) may be used for estimating the labor costs of installing various parts of warm-air heating systems.

TABLE 12-13.—APPROXIMATE LABOR-HOURS FOR INSTALLING WARM-AIR HEATING SYSTEMS FOR BUILDINGS UP TO ABOUT 50,000 CU. FT. IN VOLUME

Item	Labor-hours	Item	Labor-hours
Gravity system. Warm-air furnace only	6–14	For oil-burner-fired furnace	3– 6
Gravity system. Furnace with humidifier	7–14	System with air-conditioning unit:	
Humidifier, if separately installed	2– 4	For hand-fired furnace	3– 7
Fan (auxiliary)	2– 4	For stoker-fired furnace	4–10
Separate air-conditioning unit (as added to a gravity-system furnace)	4–12	For oil-burner-fired furnace	4–10
Pressure or forced-air system furnace with air-conditioning unit	10–24	Warm- or cold-air horizontal pipes, 100 sq. in. or less per 10 ft	1.5– 3
Stokers	4–12	100 to 400 sq. in., per 10 ft.	2– 5
Oil burners and tanks	6–16	Warm or cold air risers or stacks, 100 sq. in. or less per 10 ft	2– 4
Installing thermostat and controls		100 to 400 sq. in. per 10 ft.	3– 7
System without air-conditioning unit:		Registers with boxes, each (outlets or inlets)	1– 3
For hand-fired furnace	2– 4	Covering pipes with asbestos paper, per 100 ft	2– 6
For stoker-fired furnace	3– 6		

The labor required for installing larger and heavier furnaces and equipment may be estimated according to methods suggested in Chap. XVI on Heavy Machinery.

The labor required for installing pipes and ducts larger than about 400 sq. in. in cross-sectional area will vary approximately with the cross-sectional area rather than with the circumference because of the heavier weights (gage) of metal used and the lesser ease of handling.

The labor required for installing thermostats and controls will vary almost directly with the number of instruments, 1 to 3 hr. being required for each instrument.

The labor required for installing various accessories will vary with the kind and size of accessory and the installation requirements.

18. Equipment.—The equipment required for installing warm-air heating systems in buildings up to about 50,000 cu. ft. in volume will include all the hand tools required by the mechanics and perhaps a few special and portable tools such as saws, drills, and small soldering outfits. Sometimes ladders and sawhorses and planks for temporary scaffolding may be needed. Special equipment may be required for handling furnaces and other machinery that are too heavy to be handled by a small crew of men.

The equipment cost for a warm-air heating job, including transportation, may vary from about $5 to $15 or $20, depending on the size of the job and other conditions. Equipment costs for buildings larger than 50,000 cu. ft. will be proportionately higher.

19. Overhead and Profit.—Overhead costs on a warm-air heating job are usually based on labor costs alone, but may be based on the sum of the costs of materials, labor, and equipment. When based on labor costs, the general overhead may range from 15 to 35 per cent plus compensation insurance, social-security taxes, and like items. Compensation insurance and social-security taxes may range from about 3 to 6 per cent of the labor costs, as an average. The total overhead may range from about 20 to 45 per cent of the labor costs with an average value of about 30 to 35 per cent.

Profit may range from about 8 to 20 per cent on the sum of all other costs. If profit on the materials, or on part of the materials, has been included in the materials costs, this profit should not be included a second time.

20. Warm-air Heating Estimates.—Estimates for warm-air heating systems may be summarized to show the total costs of materials, labor, equipment, overhead, and profit. Unit costs may be computed, if desired, per warm-air outlet, per outlet (based on sum of warm- and cold-air outlets and inlets), per square foot of floor area heated, and per cubic foot of space heated. The summary may be tabulated as follows:

Item	Unit Cost (as Desired)	Total Cost
Materials.........................	$	$
Labor		
Equipment.........................		
Overhead.........................		
Profit.........................		
Total.........................	$	$

21. Illustrative Estimate.—As a general contractor, you desire to prepare an approximate estimate of the cost of a warm-air heating system for a small two-story frame residence, 26 by 28 ft. in size. Fairly complete plans and specifications are available. The warm-air heating system is a pressure system with an oil-fuel furnace and an air-conditioning unit.

Materials: An examination of the plans and specifications and of wholesalers catalogues available gave the following information:

Warm-air furnace, with jacket, smoke pipe, and dampers			= $135
Oil burner and accessories, less thermostat			= 155
Air-conditioning unit			= 125
Thermostat and controls			= 60
Warm-air registers:			
2 8 by 10 in.	at $2.00	= $ 4.00	
6 10 by 12 in.	at 2.75	= 16.50	
Cold-air registers:			
2 10 by 12 in.	at 2.75	= $ 5.50	
6 12 by 15 in.	at 4.00	= 24.00	
16 register boxes	at 0.50	= 8.00	
All registers			= 58
Warm-air pipes (26 gage):			
28 ft., 3 by 10 in.	at $0.18	= $ 5.05	
5 elbows	at 0.40	= 2.00	
88 ft., 3.5 by 12 in.	at 0.22	= 19.35	
15 elbows	at 0.45	= 6.75	
Cold-air returns (26 gage):			
74 ft., 3.5 by 14 in.	at 0.245	= 18.15	
7 elbows	at 0.55	= 3.85	
20 ft., 5.5 by 14 in.	at 0.375	= 7.50	
3 elbows	at 0.85	= 2.55	
18 ft., 8 by 28 in. trunk (No. 24 gage)	at 0.60	= 10.80	
Asbestos covering for all warm-air pipes 1 roll estimated		= 4.00	
All piping			= 80
Total materials			= $613

Labor: Assume 2 mechanics at \$2 per hour each and 2 helpers at \$1 per hour each, giving an average wage of \$1.50 per hour.

Installing furnace	=	10 hr.	
Installing air-condition unit	=	7 hr.	
Installing oil burner and tanks	=	10 hr.	
Installing thermostat and controls	=	8 hr.	
Installing registers and boxes 16 at 1.5 hr.	=	24 hr.	
Installing piping system, assume each elbow as equivalent of 2 ft. 288 equivalent feet at 2.5 hr. per 10 ft.	=	72 hr.	
Installing asbestos paper on warm-air pipes	=	4 hr.	
Total labor-hours	=	135 hr.	
Labor cost, 135 hr. at \$1.50			= \$202
Equipment, for job, estimated at			= 12
Overhead, say 30 per cent of labor cost			= 60
Profit, say 10 per cent of all other costs			= 89
Total estimated cost			= \$976

This estimate may be summarized as follows:

Item	Cost per Outlet	Cost per Warm-air Outlet	Total Cost
Materials	\$38.30	\$ 76.60	\$613
Labor	12.60	25.25	202
Equipment	0.75	1.50	12
Overhead	3.75	7.50	60
Profit	5.60	11.15	89
Totals	\$61.00	\$122.00	\$976

This estimated cost seems high for a warm-air heating plant for a small residence. If the costs were subdivided for furnace, registers and pipes, air-conditioning unit, oil burner, and thermostats, the reason is clear.

Furnace	\$172
Registers and pipes	374
Air-conditioning unit	154
Oil burner	192
Thermostat and controls	84
Total	\$976

D. AIR-CONDITIONING SYSTEMS

22. Estimating of Air-conditioning Systems.—Perhaps the best way of estimating an air-conditioning system is to study the plans and specifications, divide the system into several parts according to kinds of work, materials or machinery, and then prepare estimates for the materials and labor. The number of

parts into which an air-conditioning system may be divided will depend upon the kind of system, the work it is to do, and whether or not it is combined with the heating system. The following is suggested:

Central system. Ventilation by fan. Heat by direct radiation (split system).
- Blowers, including motors, fans, and box.
- Humidifiers.
- Air filters and washers.
- Duct or pipe system for conveying air.
- Controls.

Central system. Ventilation and part of heat by fan. Remainder of heat by direct radiation.
- Heating system for heating air. Warm-air furnace, steam coils, etc.
- Also cooling system if air is to be cooled in warm weather.
- Blowers, including motors, fans and box.
- Humidifiers.
- Air filters and washers.
- Duct or pipe system for conveying air.
- Thermostats and other controls.

Central system. Ventilation and all of heat by fan. (Hot-blast system.)
- Heating system for heating air. Warm-air funace, steam coils, etc.
- Also cooling system if air is to be cooled in warm weather.
- Blowers, including motors, fans, and box.
- Humidifiers.
- Air filters and washers.
- Duct and pipe system for conveying air.
- Thermostat and other controls.

The combined warm-air heating and air-conditioning system used in many residences and small buildings is an example of the hot-blast system.

Unit-system heaters.
- The unit complete ready to install.
- Electrical connections for the fan.
- Piping connections for the heating part (usually steam coils).
- Controls.

Unit-system coolers.
- The unit complete ready to install.
- Electrical connections for the fan.
- Piping connections for the cooling part.
- Controls.

Unit ventilators.
- The unit ready to install.
- Outside air connections.
- Electrical connections for fan.
- Water piping for humidifier.
- Controls.

Unit conditioners (heaters).
- The unit ready to install.
- Outside air connections.
- Electrical connections for fan.
- Piping connections for heating part (usually steam coils).
- Piping for humidifier.
- Controls, thermostat, switches, etc.

Unit Conditioners (Coolers).
- The unit ready to install.
- Outside air connections.
- Electrical connections for fan.
- Electrical connections for refrigerating unit.
- Piping connections for cool water.
- Piping for humidifier.
- Controls, thermostat, switches, etc.

In any one particular air-conditioning system (central or unit), all the general items listed may not be included. For example, in a unit-system heater it is assumed that the heating will be done by steam coils. If the heating were to be done by electricity, electrical connections for the heater would be needed, and obviously no steam piping would be required. Likewise, for a unit conditioner (cooler) if a refrigerating unit was used, no water-piping connections would be required.

23. Material Take-off.—When preparing a take-off for a central system, some estimators prefer to start with the blower and the various items (motors, fans, humidifiers, filters, etc.) connected with it, then to list all items in the duct or pipe system, and finally the items in the control system.

When preparing a take-off for a unit system including a number of units, some estimators like to consider each unit by itself and list it and the items connected with it before proceeding to the next unit. Other estimators prefer to list all units first, then all piping, then all electrical connections, then the controls, etc. If the job is a fairly large one, a summary sheet may be prepared, summarizing the units, piping, electrical work, controls, etc.

After the take-off has been completed, the various items may be priced, and estimates made for the labor, equipment, overhead, and profit.

24. Materials. *Central Systems.*—The assembly of a blower for a central system includes housing or casing, fan, and motor. The capacity of a fan is usually given in cubic feet of air per minute for a given outlet velocity, static pressure, and barometric reading. Manufacturers' catalogues and fan tables should be consulted for sizes, capacities, motor horsepower required, outlet velocities, weights, and prices. Outlet velocities are often limited to 1,200 or 1,400 ft. per minute.

Fans may be driven by motors, steam engines, or steam turbines. The horsepower required will vary with the fan output and static pressure. The electric motors selected should have a horsepower 10 to 25 per cent greater than that listed in the fan tables because of possible variations in static pressures. Motor speeds for alternating-current motors are approximately 570, 690, 865, 1,150, and 1,750 r.p.m.

Two types of heaters are used in fan systems, *viz.*, the cast-iron heater and the nonferrous fin-tube types. There are several designs of each on the market.

The fan, motor, heaters, and casing or housing are usually mounted on brick or concrete foundations. The casing should be designed to reduce friction resistances as much as possible.

The duct or pipe system is usually a trunk system with as many branches as desired. Sometimes two or more main-trunk ducts are used, depending upon the structure and the design. Branches lead from the mains or trunks to the outlets. The ducts are often constructed of galvanized steel or iron of suitable gage and reinforced with angles, straps, or other small structural shapes.

The outlets are usually of grillwork somewhat like warm-air registers in appearance.

Humidifiers, filters, or washers are usually located near the blower and heater. Filters or washers are usually placed between the fresh-air inlet and the blower.

The thermostatic control is usually a little more complicated than that for an ordinary warm-air heating system. Instruments may be located in the fresh-air inlet, near the air washer or filter, on the far side of the fan, and also as desired in the building. If desired, a thermostat and mixing damper may be provided for each room.

Unit Systems.—There are several kinds of unit heaters on the market with varying capacities and different methods of installation. Each unit may consist of a fan, motor, heater, or cooler, and sometimes a humidifier or dehumidifier. These units are usually sold by the manufacturer completely assembled and ready to install. Hence, it is necessary to list the units required by size, dimensions, capacity, and manufacturers' number as desired.

These units often require extra piping and electrical connections. If steam is used for heat, a two-pipe system should be provided. The electrical lines should be sufficient to carry the load.

If cold water is used for cooling, extra piping is often required to convey the water to and from the unit. If external-air inlets and outlets are required, any needed grills and ducts should be noted.

The controls may be manual, including a switch for the motor and a valve on the heater, or a thermostat. The thermostat is usually used for turning the motor on and off, but may also be used to regulate the steam.

Prices of units vary considerably according to the items included, the make, and capacity. A simple ventilating-fan unit suitable for a room may cost about $25 and up. A room-cooler unit containing a fan, motor, filter, refrigerating unit, and humidifier may cost $350 to $800. A heating unit consisting of a heater, fan, and filter may cost about $50 to $200. A simple single-thermostat control system for a unit may cost about $30 and up.

25. Labor. *Central Systems.*—The labor required for installing central air-conditioning systems may be estimated by considering the different parts of the system and estimating the

labor required for each part. Most central air-conditioning systems are installed by manufacturers, dealers, or contractors who specialize in that line of work. The bids submitted usually include all costs of the plant installed and ready to operate. The general contractor will rarely have to do the work of installation.

The labor for installing heavy blowers, heaters, motors, fans, casings, filters, washers, etc., may be estimated according to the methods suggested in Chap. XVI on Heavy Machinery.

The labor for installing duct systems will vary with size and weights of the ducts and the working conditions.

The labor for installing control systems will vary almost directly with the number of instruments. From 1 to 3 labor-hours per instrument may be allowed.

The wages of skilled mechanics may vary from about \$1.25 to \$2.25 per hour and of helpers from about \$0.65 to \$1.25 per hour. A labor gang may be composed of a foreman, mechanics, and helpers. Mechanics may include electricians, pipe fitters, sheet-metal workers, masons, and carpenters.

TABLE 12-14.—APPROXIMATE LABOR-HOURS REQUIRED FOR INSTALLING UNIT SYSTEMS

Item	Labor-hours	Item	Labor-hours
1. Unit-system heaters:		4. Unit conditioners (heaters):	
Install, including pipe and electrical connections..	2–6	Install with pipe and electrical connections...	3–6
Additional piping, per 10 ft....................	1–2	Outside air connections.	2–5
Thermostat controls.....	1–3	Extra piping per 10 ft....	1–2
2. Unit-system coolers:		Thermostat controls.....	2–4
Install including water piping and electrical connections...........	3–6	5. Unit conditioners (coolers):	
Additional piping per 10 ft....................	1–2	Install with pipe and electrical connections...	3–6
Thermostat controls.....	1–3	Outside air connections..	2–5
3. Unit ventilators:		Extra piping, per 10 ft...	1–2
Install with electrical connections..............	1–3	Thermostat controls.....	1–3
Outside air connection...	2–5		

Unit Systems.—The labor required for installing unit systems will vary considerably with the different units and the working conditions. The values given in Table 12-14 are approximate only. It is assumed that steam and water pipes are available near the location of the unit. Additional time must be allowed for running pipe lines from basement or other floors and rooms.

Diagram 12-4 (page 629) may be used for estimating the labor costs of installing air-conditioning units.

A labor gang for installing unit heaters may consist of one mechanic with one or two helpers, or two mechanics with two or more helpers. Usually the services of both an electrician and pipe fitter will be required.

26. Equipment. *Central System.*—The equipment required for installing a central system will include all the hand tools of the mechanics, and special tools and equipment needed for placing and assembling heavy and cumbersome machinery. Usually some temporary scaffolding may be required. Equipment costs for a central-system job including transportation and miscellaneous supplies may range from about $10 up to $100 or so. Some estimators allow about $5 or $10 plus 1 to 2 per cent of material costs.

Unit System.—The equipment required for installing unit systems will usually consist of the hand tools of the mechanics plus a ladder, stepladder, and temporary scaffolding in some cases. The equipment cost may be assumed at $1 to $2 per unit plus transportation. The minimum for any one job may range from about $3 to $5.

27. Overhead and Profit.—Overhead for installing air-conditioning systems is often based on labor costs. General overhead may range from about 15 to 35 per cent of the labor cost, plus compensation insurance, social security taxes, etc. Total percentage for overhead may vary from about 20 to 45 per cent of the labor costs.

Profit on air-conditioning jobs may range from about 8 to 20 per cent of the sum of all other costs. If, when estimating unit systems, the price of a unit includes profit, this profit should not be included again.

28. Air-conditioning Estimates.—Estimates of the cost of an air-conditioning system should be summarized to show total costs of materials, labor, equipment, overhead, and profit.

Unit costs of central systems may be computed per cubic foot of space, or per square foot of floor area. Unit costs of unit systems may be computed per unit, per cubic foot of space, or per square foot of floor area. Unit cost per square foot of floor area appears to be the unit selected by many estimators. Central air-conditioning systems may cost from about $1 to $2 per square foot of floor area. In each case, information should be given in regard to kind of building, occupancy, and kind of air-conditioning system. The estimate may be summarized as follows:

Item	Unit Cost as Desired	Total Cost
Materials..........................	$	$
Labor..............................		
Equipment..........................		
Overhead...........................		
Profit.............................		
Total..............................	$	$

CHAPTER XIII

PLUMBING

1. *Estimating of Plumbing.*—The plumbing work on a job is almost always sublet to a subcontractor specializing in this kind of work. This subcontractor (or his plumbing estimator) is a man capable of preparing detailed and accurate estimates. Consequently, the general contractor (or his estimator) rarely needs to be able to prepare an accurate and detailed plumbing estimate, but he should have a good general knowledge of estimating so that he can check intelligently and can determine the reasonableness of the detailed bids submitted by the plumbing contractors. It is the purpose of this chapter to help supply the general knowledge that the general contractor or his estimator may need for checking plumbing bids and estimates.

On some jobs, a separate set of plumbing plans, diagrams, and specifications are furnished in detail so that it is an easy matter for the estimator to take off accurately all plumbing materials required. With such plans, a good estimator can prepare an accurate list of everything that will be required.

On other jobs, the plans show merely the locations of the fixtures and the specifications state the types and makes. In such cases, the plumbing estimator must be able to visualize the work in detail and perhaps make drawings or sketches of the piping so that he can estimate reasonably accurately all the required pipings and fittings as well as the fixtures.

Some architects, when preparing the plans and specifications, do not describe all the plumbing work in detail, but insert one or more general clauses stating that all plumbing work must be done in accordance with all state and local codes and regulations and also that the work must pass the inspection of all authorities having jurisdiction, usually a municipal plumbing inspector. Such clauses place upon the estimator the need of determining all the requirements relating to kinds and sizes of pipes, stacks, vents, traps, and other details.

Plumbing work is usually divided into rough plumbing and finish plumbing. Rough plumbing includes all sewer pipes, water and gas pipes, vents, drains, etc., required and finish plumbing includes the fixtures and their accessories.

The plumbing estimate for either rough or finish work may be divided into materials, labor, equipment, overhead, and profit. Rough and finish plumbing are usually estimated separately, though in some instances the materials, labor, and equipment may be estimated separately, and overhead and profit figured on the total plumbing work.

A. ROUGH PLUMBING

2. Rough Plumbing Take-off.—The take-off for the rough plumbing should include all materials for

Water pipes, both exterior and interior.
Gas pipes, both exterior and interior.
Sewer pipes.
Drains.
Soil and vent stacks.
Soil, waste, and vent pipes.
All roughing work required for fixtures.

The take-off must show the size, length, kind (cast iron, copper, lead, glazed clay, galvanized, black), weight (standard or extra heavy), and other details of all pipe; materials needed for calking cast-iron soil, waste, and vent pipes; and all pipe fittings such as unions, nipples, caps, hangers, elbows, or bents, Y's, and T's. The take-off should also list kinds and sizes of all valves, traps, plugs, exterior grease traps, cleanouts, etc. If trenching is required, the length, average depth, and kind of soil should be noted.

Explanations of some of the rough plumbing terms follows:

A sewer pipe is the section of drain piping extending from the street sewer to the building. This pipe may be of cast iron or glazed vitrified clay, 4 in. or larger.

The house drain is the drain pipe inside the building (horizontal) extending from the sewer pipe to the stacks. It may be of cast iron, wrought iron, or steel.

Stacks and vertical pipes extend from the house drain to the roof. Stacks are usualy made of cast-iron pipe, though wrought-

iron or steel pipe with sanitary fittings may be used. Stacks may be soil, waste, or vent.

Between the various fixtures and the stacks and connecting them are three kinds of pipes, *viz:*

Soil pipes, draining a toilet or closet.

Waste pipes, draining all other fixtures.

Vent pipes, affording ventilation and preventing siphonage of water in traps.

Soil and waste pipes must be located below the fixtures they serve.

Vent pipes are usually connected above the fixture or trap to be vented.

The rough plumbing take-off should be accurate in detail. All materials should be listed in an orderly manner so that totals may be readily computed, prices inserted, and costs computed.

The local water company usually runs the water pipe from the water main to the lot line and installs a shutoff there. The plumber runs the water pipe from the shutoff to the building. The water company may furnish and install the water meter, or the plumber may do the installing.

The municipality usually lays the sewer from the nearest main to the lot line, and the plumber lays the sewer from the lot line to the building.

The local gas company usually lays the gas pipe from the mains into the building and furnishes and installs the meter.

3. Materials for Rough Plumbing.—Pipe of various kinds are usually priced per linear foot with other details being given. Sometimes the price is per piece, with length and other details being given, or per pound or ton with size, thickness, and other details being given.

Pipe fittings may be priced per piece, per dozen pieces, or per 100 pieces, with kinds, sizes, and other details being given. Sometimes they are priced by the pound.

Valves, traps, and special fittings are usually priced per piece with size, kind, material, and other details noted.

The data given in this chapter in regard to materials and prices are approximate only and are subject to change from time to time, as manufacturers modify their products and prices change. The data are included for the purpose of giving the estimator

some information for making approximate estimates and for checking estimates submitted by plumbers.

Lead and oakum are usually sold by the pound. About 3 lb. of pig lead and ¼ lb. of oakum are needed for one joint of 4-in. cast-iron pipe. Lead may cost $0.10 to $0.16 per pound, and oakum $0.07 to $0.16 per pound.

Vitrified-clay sewer pipe comes in various sizes and lengths (usually 2 to 4 ft.). The different diameters are priced per foot of length delivered at the job. Average price ranges are about as follows. The 8 and 12 in. are single-strength, and the 24 in. is double-strength pipe.

8-in. diameter, $0.30 to $0.45 per lineal foot.
12-in. diameter, $0.50 to $0.55 per lineal foot.
24-in. diameter, $2.00 to $3.50 per lineal foot.

Cast-iron soil pipe comes in various diameters and weights. The length of each section is usually 5 ft., and each section may be single hub or double hub. Double-hub sections are useful when short lengths are required. Each double-hub section, when cut into two parts, will provide two short sections each with a hub at one end. Diameters vary from about 2 to 10 in., the 3-, 4-, 6-, and 8-in. diameters being more common. The pipe may come in standard weight or extra-heavy weight. The extra-heavy weight is preferred because of its greater strength.

TABLE 13-1.—SIZES, APPROXIMATE WEIGHTS, AND PRICES OF 5-FT. SECTIONS OF CAST-IRON SINGLE-HUB SOIL PIPE

A double-hub section will weigh (and cost) about 5 per cent more than the corresponding single-hub section.

Diameter, inches	Weight per 5-ft. length, pounds		Approximate prices of 5-ft. lengths	
	Standard	Extra heavy	Standard	Extra heavy
2	18	27	$0.65–$1.00	$0.95–$ 1.45
3	26	47	0.90– 1.45	1.60– 2.45
4	35	65	1.20– 1.80	2.15– 3.25
5	45	85	1.45– 2.25	2.75– 4.15
6	55	100	1.75– 2.75	3.25– 4.80
7	..	135	....	4.30– 6.50
8	..	170	....	5.40– 8.10
10	..	225	....	7.20– 10.50

Cast-iron soil pipe is usually sold by the manufacturers to wholesalers and large dealers by the ton with size, thickness, and other details given. Prices (1946) may range from about $60 to $80 per ton, f.o.b. factory. Prices vary somewhat with the pipe diameters, the smaller diameters costing more. Small dealers, plumbers, and retailers usually price the soil pipe by the 5-ft. section, diameter and weight being given. It is easier for the estimator to figure soil pipe by size and length than by weight. Prices delivered at the job may range from about $80 to $130 per ton.

Table 13-1 gives approximate weights and prices of 5-ft. cast-iron soil pipe. Dealers price lists should be consulted for accurate estimates.

Three-inch diameter cast-iron soil pipe is about the smallest size that should be used. Four inch is recommended as a minimum size. Table 13-2 gives the approximate maximum number of fixtures that should be connected to a soil pipe.

TABLE 13-2.—MAXIMUM NUMBER OF FIXTURES CONNECTED TO PIPE

Diameter of pipe, inches	Soil pipe alone, water closets, and toilets	Combined waste and soil-pipe fixtures
2	...	8
3	2	18
4	15	60
5	35	140
6	70	280
7	120	500
8	200	800
10	400	1,500

Cast-iron soil-pipe fittings are usually estimated by the piece, and the price per piece obtained from the dealer. However, fittings are often sold by the manufacturer by weight, the price per ton averaging about 1.5 to 2.5 times that of the regular soil pipe, depending upon the manufacturing difficulties. For rough estimating, approximate prices of various fittings may be used without causing appreciable errors in the totals. Dealers' catalogues and price lists should be consulted for accurate estimates.

TABLE 13-3.—APPROXIMATE PRICES OF SIMPLE CAST-IRON SOIL-PIPE FITTINGS

Size of pipe, in.	Quarter and eighth bends		T's and Y's		Cast-iron cleanout T's and Y's	
	Standard	Extra heavy	Standard	Extra heavy	Standard	Extra heavy
2	$0.20–$0.35	$0.25–$0.45	$0.40–$0.60	$0.50–$0.80	$1.00–$1.40	$1.25–$1 50
3	0.28– 0.50	0.50– 0.80	0.50– 0.80	0.70– 1.00	1.10– 1.60	1.40– 1.85
4	0.36– 0.60	0.65– 1.05	0.60– 0.95	0.80– 1.35	1.25– 2.05	1.55– 2.40
5	0.45– 0.80	0.85– 1.35	0.75– 1.20	1.00– 1.60	1.55– 2.55	2.00– 3.00
6	0.55– 0.95	0.95– 1.50	0.85– 1.45	1.20– 1.95	1.85– 3.00	2.50– 3.50
7	....	1.20– 1.90	....	1.45– 2.50		
8	....	1.50– 2.40	....	1.80– 3.20		
10	....	1.90– 3.20	....	2.40– 4.10		

TABLE 13-4.—STEEL AND WROUGHT-IRON PIPE DIAMETERS, WEIGHTS, LIST PRICES, AND APPROXIMATE DISCOUNTS

Prices are for standard weights

Nominal size, in.	Weights, black finish, lb. per foot			List price, standard weight per foot	Approximate discounts, per cent			
					Wrought steel		Wrought iron	
	Nominal or standard	Extra strong	Double extra strong		Black	Galvanized	Black	Galvanized
½	0.85	1.08	1.71	$0.085	64.5*	55.5*	30*	14*
¾	1.13	1.47	2.44	0.115	64.5*	55.5*	30*	14*
1	1.68	2.17	3.65	0.170	64.5	55.5	30	14
1¼	2.28	2.99	5.21	0.230	64.5	55.5	30	14
1½	2.73	3.63	6.40	0.275	64.5	55.5	34	16.5
2	3.67	5.02	9.02	0.370	64.5	55.5	33.5	16
2½	5.81	7.66	13.69	0.585	64.5	55.5	27.5	12.5
3	7.61	10.25	18.58	0.765	64.5	55.5	27.5	12.5
4	10.88	14.98	27.54	1.090	62	52.5	27.5	12.5
5	14.81	20.77	38.55	1.485	62	52.5	28.5	15
6	19.18	28.57	53.16	1.920	62	52.5	28.5	15

* Discounts estimated same as for 1-in. pipe.

Copper-bearing steel pipe costs about 12 to 15 per cent more than ordinary steel pipe.

Pipe 1 to 3 in. in diameter is butt-welded.

Pipe 3.5 to 6 in. in diameter is lap-welded.

In this chapter, a plumbing team will be assumed to consist of one plumber and one helper unless otherwise specified. Hence, the actual labor-hours will be twice the team-hours.

TABLE 13-11.—APPROXIMATE TEAM- AND LABOR-HOURS REQUIRED FOR PLUMBING WORK

Kind of work	Team-hours	Labor-hours
Digging a 6-ft. trench and backfilling, per lineal foot	0.25–0.60	0.5–1.2
Installing sewer pipe, 4 in. to 12 in., in trench, per ft	0.10–0.30	0.2–0.6
House drains and stacks, cast-iron soil pipe:		
3 and 4 in. diameter, lead and oakum joints, per joint	0.25–0.60	0.5–1.2
5 and 6 in. diameter, lead and oakum joints, per joint	0.45–0.75	0.9–1.5
Pipe work, steel and wrought-iron threaded pipe, including threading, hanging, and connecting, assuming one thread cut per joint:		
½-in. pipe, and smaller, per joint	0.15–0.25	0.3–0.5
¾- and 1-in. pipe, per joint	0.20–0.30	0.4–0.6
1¼- and 1½-in. pipe, per joint	0.25–0.40	0.5–0.8
2- and 2½-in. pipe, per joint	0.35–0.55	0.7–1.1
3- and 3½-in. pipe, per joint	0.45–0.75	0.9–1.5
4-in. pipe, per joint	0.65–1.00	1.3–2.0
Copper tubing:		
⅜ and ½ in. diameter, per joint	0.15–0.35	0.3–0.7
¾ in. diameter, per joint	0.20–0.40	0.4–0.8
(Usually fewer joints, ⅓ to ¼, will be required for copper tubing than for steel pipe of equal length)		
Roughing work:		
Urinal with stall	3– 8	6–16
Water closet	6–12	12–24
Lavatory	4–10	8–20
Shower with stall	6–10	12–20
Bath tub	4– 8	8–16
Bath tub with shower	6–12	12–24
Kitchen sink	4– 7	8–14
Slop sink	3– 6	6–12
Laundry tubs, pair	4– 7	8–14
Floor drain	2– 4	4– 8
Grease trap	3– 6	6–12
Valves, faucets, etc., installed with rough plumbing:		
1-in., or less, pipe connection, each	0.25–0.50	0.5–1.0
1- to 2-in. pipe connection, each	0.35–0.65	0.7–1.3
2-in. and over pipe connection, each	0.50–0.75	1.0–1.5
Testing plumbing system when required, per fixture	1–2	2–3

The time required for a certain item of plumbing work will vary considerably, depending on the particular work, the working conditions, and the skill and inclination of the plumber. Roughing work for plumbing fixtures may be estimated in labor-hours or team-hours required per fixture without going into further details. Labor for pipework may be more accurately estimated per joint instead of per 100 lin. ft. of pipe, with kind of pipe and diameter given. The labor per joint will include all threading, hanging, and connecting needed. The larger the pipe, the more labor-hours required. It is assumed that an adequate supply of nipples, unions, couplings, and other fittings are available.

Approximate labor-hours and team-hours required for various kinds of rough plumbing work are given in Table 13-11.

When estimating threaded joints, each coupling and valve counts as two joints, a T as three joints, etc. The labor-hours and team-hours given for threaded pipe joints in the table are based on the assumption that one pipe thread must be cut for each joint. When no thread needs to be cut, the time given may be reduced 35 to 50 per cent. Each fitting will require two joints on an average.

The wages for plumbers may vary from about $1.25 to $2.25 per hour, with average values between $1 and $2. Wages of plumbers' helpers may vary from about $0.65 to $1.25 per hour, and in any locality are approximately equal to about half the plumber's wage.

Diagram 13-1 (page 630) may be used for estimating the labor cost of pipe work and Diagram 13-2 (page 631) for the labor cost of rough plumbing work when the hourly combined wage of plumber and helper is known and the time required may be reasonably assumed.

5. Equipment.—The equipment needed will vary with the character and size of the job. Each team may need the following:

Pipe cutters.
Pipe threaders.
Vise, and frame for holding vise.
Workbench.
Wrenches.
Calking tools.
Lead-melting pot.
Lead.

Oakum for calking.

Blowtorch.

Hammers, chisels, and other small tools.

Ladders, sawhorses and planks, etc., for temporary scaffolds.

The cost of a set of tools required for one team will be comparatively little for one job. The cost of transporting equipment to and from the job must not be neglected. The cost will vary with the magnitude of the job and the length of time required. Equipment costs per team per job may range from $5 or so up to $20 or $25.

6. Overhead and Profit.—Overhead on rough plumbing jobs may be based on labor costs alone or on the sum of labor, materials, and equipment costs. If costs of materials are estimated at retail prices delivered at the job, then no overhead and profit on materials should be included in the estimate because these retail prices include allowances for these items.

General overhead, based on labor, may range from 15 to 35 per cent of the labor costs, plus compensation insurance, social security and other taxes. Compensation insurance for plumbers varies in different states, and may range from 1 to 5 per cent of the labor wages, with about 3 per cent as the average. Total overhead based on labor costs alone may range from about 20 to 45 per cent with an average of about 30 per cent.

Other items that are usually included in the overhead are the costs of all fees and permits to be paid for by the contractor. The water company and sewer department charge for extending the water pipes and sewers to the lot line. The gas utility charges for laying the gas pipe from the main into the building and installing the meter. Sometimes these charges are paid by the owner directly, and sometimes they are paid by the contractor. If paid by the contractor, such charges may suitably be included in the overhead costs. The costs of these items are in addition to the percentages given.

If profit has not been included in the material prices, the percentage allowed for profit may range from 8 to 20 per cent of the sum of all other costs. If profit on materials has been included in the material prices, the job profit should be figured on the labor and equipment costs.

7. Summary.—The rough plumbing estimate should be tabulated and summarized to show the total costs of materials, labor,

Materials estimate, Local prices (1946) are used.

Sewer line,	100 ft. (20 pieces), 4-in. soil pipe	at 2.40 per piece	= $ 48
	15 ft. (3 pieces), 2-in. drain pipe	at 1.35 per piece	= 4
	7 fittings for 4-in. pipe	at 1.25 each	= 9
	4 fittings for 2-in. pipe	at 0.75 each	= 3
	2 cast-iron traps	at 1.50 each	= 3
	1 increaser for 4-in. pipe	at 2.00 each	= 2
	1 basement-floor drain and trap	at 3.00 each	= 3
	Total		= $ 72
Water line,	200 ft., ¾-in. galvanized steel pipe	at 7.50 per 100 ft.	= $ 15
	50 fittings	at 0.10 each	= 5
	2 faucets ¾ in.	at 1.00 each	= 2
	1 valve ¾ in.	at 1.00 each	= 1
	Total		= $ 23
Gas line,	52 ft., ¾-in. black steel pipe	at 7.00 per 100 ft.	= $ 4
	16 fittings	at 0.10 each	= 2
	Total		= $ 6

Materials total = $101

Labor estimate. Local wages, plumber $2, helper $1, total for team of $3 per hour.

Sewer line. Trench, 35 ft. long, 7 ft. deep, dug and backfilled by laborer, 35 hr. at $0.80	= $ 28
15 joints of 4-in. pipe at 0.40 hr. = 6.00 team-hours	
10 joints of 2-in. pipe at 0.36 hr. = 3.60 team-hours (most pipe ends threaded)	
9.60 team-hours at $3	= 29
Water line. Trench, 35 ft. long, 5 ft. deep, dug and backfilled by laborer. 25 hr. at $0.80	= 20
97 joints of ¾-in. pipe at 0.12 = 11.67 team-hours at $3 (almost all pipe ends threaded at shop)	= 35
Gas line. 29 joints of ¾-in. pipe at 0.12 hr. = 3.52 team-hours at $3 (most pipe ends threaded at shop)	= 11
Roughing work, water closet 8 hr., lavatory 5 hr., bath tub and shower 10 hr., kitchen sink 6 hr.,	

laundry tubs 5 hr., floor drain installed 3 hr., or a total of 37 team-hours at $3	= 111	
Total labor		= $234
Equipment: All equipment charges, including lead and oakum for calking, and transportation of tools to and from shop, estimated		= $ 20
Overhead: Taken as 30 per cent of labor ($234)	= $ 70	
Gas company charge $30 plus plumbing permit $8	= 38	
Total overhead		= $108
Profit: Taken as 10 per cent of all other costs ($463)		= $ 46
Rough plumbing total		= $509

B. FINISH PLUMBING

9. Finish Plumbing Take-off.—The take-off for the finish plumbing will include a list of all items and fixtures that are to be furnished and installed by the contractor. The listing should include for each fixture a brief note stating the kind, size, and make of fixture and any other information necessary for pricing. For example, a complete description of a bath tub should include the following:

Tub, size, leg, or built in, corner or recess (if built in), style, finish, and color.

Accessories and fittings, number of each, style, make, finish.

Shower if included with tub. Shower accessories, names, number, style, make, finish.

Pole and curtain, if included, together with pole fittings, make, finish.

Items that may be included in a finish plumbing take-off are lavatories, urinals, closets, showers, bath tubs, foot baths, slop sinks, kitchen sinks, laundry tubs, washers, water softeners, and all extra and special items given in the plans and specifications. Accessories are usually included with the fixtures. If not so included, all accessories must be listed separately. Other items that are sometimes furnished and installed by the pumber include gas stoves (kitchen), laundry stoves, and water heaters. It should be noted as to what fixtures are to be piped for hot, cold, and soft water as the case may be. The water meter is usually furnished by the local water company, and may or may not be installed by the plumber. The gas meter is usually furnished and installed by the local gas company.

Listing the plumbing fixtures, though a simple process, requires care in noting and counting all fixtures shown on the plans, and noting all the specification requirements regarding make of fixture, catalogue number if given, size, finish, and accessories. If the catalogue number is given, the price may be obtained from the catalogue (with notes in regard to discounts, freight, etc.). It should be noted if the price is for fixtures complete with accessories or if fixtures and accessories are priced separately. Accessories for a bath tub include faucets, supply pipes, wash and waste pipes, traps, shower, shower faucets and pipes, pole and curtain, and soap dishes.

TABLE 13-12.—APPROXIMATE PRICES OF MEDIUM-GRADE PLUMBING FIXTURES AND ACCESSORIES

Item	Fixture	Accessories	Total fixture and accessories
Lavatory	\$ 8–\$ 25	\$ 4–\$10	\$ 12–\$ 35
Water closet, complete	....	....	15– 50
Urinal, one stall with stall	20– 50	3– 10	23– 60
Shower, without stall	3– 10	3– 10	6– 20
Shower, with stall	30– 65	5– 10	35– 75
Bath tub, with legs	15– 40	5– 15	20– 55
Bath tub, built in	35– 100	5– 25	40– 125
Bath tub and shower	35– 100	15– 50	50– 150
Foot bath	10– 40	3– 8	13– 48
Kitchen sink and dish-washing compartment	50– 100	8– 20	60– 120
Kitchen sink, double drain	29– 75	6– 15	35– 90
Kitchen sink, single drain	15– 50	6– 12	21– 62
Kitchen sink, small single drain	12– 20	4– 10	16– 30
Slop sink	6– 12	3– 5	11– 17
Laundry tubs, pair	7– 20	3– 7	10– 27
Gas range, cooking	30– 150	0– 25	30– 175
Gas laundry stove	2– 15	....	2– 15
Water softener, large, 60,000 grain	....	....	100– 200
Medium, 40,000 grain	....	....	75– 150
Small, 20,000 grain	....	....	50– 100
Water heater, gas, automatic, 20 gal	....	....	40– 90
Gas, automatic, 40 gal	....	....	60– 140
Gas, side arm	....	....	5– 30
Tanks, for water, vary with size up to 100 gal. uninsulated	....	....	10– 30
Insulated	....	....	20– 50

Accessories for a kitchen sink would include faucets, supply pipes, waste and drain pipes, screens, traps, legs (if any), cabinet (if any), and drainboard (if separate).

10. Materials for Finish Plumbing.—The costs of the fixtures and accessories vary greatly with regard to make, kind, type, and quality. The best and most accurate way of obtaining the costs of the materials is to consult the dealer (or dealers) and enter the price of each fixture in its proper place in the take-off. Fixtures and accessories are usually delivered packed or crated at the job, but may be delivered unpacked and ready to install.

Table 13-12 gives approximate prices of medium-grade fixtures and accessories.

TABLE 13-13.—APPROXIMATE TEAM- AND LABOR-HOURS REQUIRED FOR INSTALLING FIXTURES AND ACCESSORIES

Fixture	Team-hours	Labor-hours
Lavatory	3– 5	5– 9
Water closet	3– 6	5–10
Urinal with stall	6–10	12–20
Shower with stall	12–16	20–30
Shower without stall	3– 5	5–10
Bath tub	5–10	10–20
Bath tub with shower	7–15	14–30
Foot bath	4– 8	8–15
Laundry tubs, pair	3– 5	6–10
Kitchen sink, small	3– 6	6–12
Kitchen sink, large	4– 8	8–15
Slop sink	3– 5	6–10
Gas laundry stove	2– 3	3– 5
Gas kitchen range	2– 4	3– 7
Water heater, gas, automatic with tank	3– 7	5–12
Water heater, gas, side arm	3– 6	5–10
Water tank	3– 5	5– 9
Water softener	3– 6	5–12

11. Labor.—The labor required for finished plumbing is that required for installing and connecting up the fixtures and accessories. Sometimes the fixtures and accessories are delivered packed and crated. Then they must be unpacked and assembled as well as installed.

Installing and connecting fixtures and accessories is usually done by men working in two men teams, each team consisting of one plumber and a helper. Sometimes a plumber needs a second helper when the fixtures are heavy and there is much lifting and moving to be done.

The team time required for installing fixtures will depend on the type, kind, and size of fixture, the number of accessories, the working conditions, and the skill and inclination of the men.

Approximate team- and labor-hours are given in Table 13-13.

Wages for finish plumbing work are the same as for rough plumbing. Plumbers' wages vary from about $1.25 to $2.25 per hour, and helpers' wages from about $0.65 to $1.25 per hour, giving two man team wages of about $2 to $3.50 per hour.

Diagram 13-3 (page 632) may be used for estimating the labor cost of finish plumbing work when the hourly wages of plumber and helper are known and the time required may be reasonably assumed.

12. Equipment.—The equipment required for installing fixtures and accessories will usually include only the ordinary plumber's hand tools. Other equipment, such as pipe threaders, scaffolding, and calking outfits, will rarely be needed.

Equipment costs for finished plumbing work may range from about $2 or $3 to $5 or $10 per team, depending upon the magnitude of the job and the time required.

13. Overhead and Profit.—Overhead on finish plumbing work is usually based on labor costs. The percentage will be practically the same as for rough plumbing work, say 20 to 45 per cent of the labor costs, with an average value of about 30 per cent.

Permits for installing fixtures are sometimes required, and may cost about $1 per fixture. The cost of these permits may be included in the overhead.

Profit is usually based on the sum of all other costs if no profit has been charged on the fixtures. If the prices for the fixtures include profit, then the job profit should be based on the sum of labor, equipment, and overhead costs. Percentages charged for profit may range from about 8 to 20 per cent.

14. Summary.—Estimates for a finish plumbing job will include materials, labor, equipment, overhead, profit, and total cost. The cost per fixture is sometimes computed. If desired, a summary may be prepared as in Art. 7 of this chapter.

15. Illustrative Estimate of Finish Plumbing.—Prepare an approximate cost estimate for the finish plumbing for the six-room house of the Illustrative Estimate of Rough Plumbing described in Art. 8 of this chapter.

It is assumed that the owner has looked over the plumbing-fixture catalogue with the contractor and has selected the fixtures desired. The following list gives the fixtures and prices. The prices are retail and include plumbers' profit. Prices are for fixtures complete with accessories.

Materials:

30-gal. automatic gas water heater	= $55	
Twin laundry tubs	= 15	
Two-burner gas laundry stove	= 5	
42-in. left-hand-drain apron-front kitchen sink	= 36	
Built-in corner bath tub with shower and curtains	= 83	
Closet or toilet	= 32	
Wall lavatory	= 21	
Total		= $347

Labor installation. Plumber and helper, $3 per hour

	Team-hours		
Gas water heater	5		
Twin laundry tubs	4		
Gas laundry stove	2		
Kitchen sink	6		
Bath tub, shower, etc.	12		
Closet	6		
Lavatory	4		
Total team-hours	39	at $3	= $117
Equipment, estimated as $8 per job			= 8
Overhead, 30 per cent of labor ($117)			= 35
Profit, 10 per cent of labor, equipment, and overhead ($1600) (profit on materials included in materials prices)			= 16
Finish plumbing total			= $423

C. TOTAL OR COMBINED PLUMBING ESTIMATES

16. Combined Plumbing Estimates.—On many jobs, the plumbing contractor estimates both the rough and finish plumbing and submits a bid for the entire job. When preparing such estimates, the rough and finish plumbing costs are usually estimated separately and then the sum of both costs is found. Sometimes the estimator estimates the materials, labor, and equipment separately for the rough and finish plumbing, and then estimates overhead and profit for the combined job.

17. Illustrative Estimate.—For an example of an estimate for a combined plumbing job, the following tabulation has been prepared, using the costs estimated in the preceding estimates for rough and finish plumbing.

Item	Rough plumbing	Finish plumbing	Total
Materials	$101	$247	$348
Labor	234	117	251
Equipment	20	8	28
Overhead	108	35	143
Profit	46	16	62
Total	$509	$423	$932

CHAPTER XIV

ELECTRICAL WORK

A. ELECTRICAL WORK IN GENERAL

1. Electrical Work.—The electrical work on a building is almost always done by a subcontractor experienced in this kind of work. The estimates for this work are usually prepared by the subcontractors who submit bids. The general contractor, or his estimator, rarely has to prepare estimates for electrical work except, perhaps, as a check on the estimates and bids submitted by the subcontractors.

The purpose of this chapter is to give enough information regarding estimates for electrical work so that the general contractor, or his estimator, will be able to prepare approximate estimates for checking and for determining whether or not the bids submitted for electrical work are reasonable.

The electrical work required for a building may be divided into two parts, the wiring or "rough" work, and the fixtures or "finish" work.

The electrical wiring or rough work is installed as the building is erected. This rough work includes nearly everything from the place where the supply mains enter the building up to the outlets in the walls or ceilings. Some of the materials to be considered are wire, conduit, switches, fuses, fuse boxes, outlet boxes, and floor plugs.

Electrical wiring may be "open" or "concealed." Open wiring is rarely used except on temporary and hasty construction jobs. Many localities now prohibit the installation of open wiring. The methods used in concealed wiring are "conduit" and "knob and tube." The use of knob and tube work is decreasing and is prohibited in many instances. Conduit work may be of the rigid-, flexible-, or armored-cable types.

The electrical fixtures are usually installed after the building is practically completed; *i.e.*, after the lathing and plastering are done and, in many cases, after the painters are through.

An estimate for the electrical fixtures is rarely called for because the selection of the fixtures is usually left to the owner or architect. Sometimes a lump sum is provided for in the contract for the electrical fixtures with the understanding that if the fixtures selected cost more than this sum, the owner pays the difference, and vice versa.

At the present time, the National Electrical Code is used to a large extent throughout the United States. Some states and localities have their own special codes which differ somewhat from the national code. In many instances, the national code is required with some exceptions and additions. The code regulations governing the particular job should be carefully studied before a detailed electrical estimate is prepared.

A set of standard symbols for electrical wiring work has been adopted and is in use in most parts of this country. Some localities have their own special symbols which they use in place of, or in addition to, the standard symbols. Consequently, the electrical estimator should be familiar with local symbols as well as with the standard symbols.

2. Estimating Electrical Work.—The items included in an estimate of electrical work are materials, labor, equipment, overhead, and profit.

The cost of electrical work will depend upon the amount, kind, quality, and price of the required materials; the kind of work; the skill, inclination, and wages of the workmen; the equipment required; the overhead expense, including shop expense, general overhead, compensation insurance, and social-security taxes; and the profit charged. Code requirements, local ordinances, and labor regulations also affect the costs.

The accuracy of the estimate will depend upon the time and effort exerted when preparing the estimate; upon the skill and qualifications (experience and judgment) of the estimator; and upon the method followed.

3. Estimating with Plans.—In most cases, it is undoubtedly more scientific, businesslike, and accurate to make a detailed analysis of the circuits. Such an analysis is almost necessary when the experience of the estimator is limited or when unusual conditions are met. An analysis is best made from the architect's or electrical engineer's plans and specifications. The plans should be gone over in a systematic manner, and all outlets

as well as corresponding paragraphs in the specifications should be checked with a red pencil in order to be certain that everything is included, and also to avoid estimating twice on the same items. If complete and detailed data are given in the plans and specifications, the estimator has only to write down the details on an analysis sheet. From this, the cost of material is readily determined and the labor-hours are estimated.

If complete detailed wiring plans are not available, it is often desirable for the electrical contractor to prepare his own detailed layouts or wiring plans and have the plans approved before starting work. The layout should show the location of each circuit on each floor and should show all cutouts, switches, meters, plugs, fuse boxes, etc.

4. Estimating without Plans.—When detailed plans and specifications for the electrical work are not furnished, it is advisable for the estimator to go over the general plans and specifications very carefully and note the location of all outlets, such as switches, meters, plugs, fuse boxes, and cutouts.

A very useful aid for the estimator in determining the details is for him to sketch the floor plans of the building upon sheets of cross-sectional paper having eight divisions per lineal inch. One or more sheets should be used for each floor. A scale of $\frac{1}{4}$ or $\frac{1}{8}$ in. to the foot will usually be satisfactory. By jotting down other information as to the kind of building, walls, and especially any unusual conditions, the estimator can readily get the necessary data for making reliable estimates. Sketches prepared in this way aid materially not only in making estimates of material and labor, but they are also of great value to the workmen who install the wiring. These sketches also help in eliminating a large part of the disputes with customers, since disputes are usually due to some misunderstanding concerning the work to be done.

After the sketches are prepared, the estimator should go over them with the architect or owner to determine if the estimator's ideas are reasonably correct and satisfactory. Then, after the sketches have been approved, the estimator can prepare the estimate.

5. Approximate Estimates Based on Cost per Outlet.—An approximate and common method of estimating electrical-wiring costs on small- and medium-sized jobs is to base the estimate on

the average cost per outlet. When the estimator has complete and up-to-date information at hand, this method of estimating is satisfactory for a quick preliminary estimate and for a check on a more detailed estimate.

There are many variables to be considered when estimating wiring costs. Among these variables are the kind of wiring (conduit or knob and tube), code used, local ordinances, kind and quality of materials specified, material costs, labor costs, labor regulations, kinds and quality of labor, and difficulties pertaining to the particular job.

TABLE 14-1.—APPROXIMATE COSTS OF ELECTRIC OUTLETS

Outlet	Knob and tube	Flexible and thin-wall rigid (light) conduit	Rigid heavy conduit
Electric wiring (52, 110, 220 volt):			
Main switch	\$3.00–\$ 7.50	\$3.75–\$ 9.00	\$4.50–\$11.50
Combination switch and fuse	5.50– 10.00	6.00– 12.00	7.00– 15.00
Fuse box	3.00– 7.50	3.75– 9.00	4.50– 11.50
Cutout box	2.50– 5.00	3.00– 6.50	3.75– 7.50
Meter (less meter)	3.00– 7.50	3.75– 7.50	4.50– 9.00
Switches, 2-way	2.00– 5.00	2.50– 5.75	3.00– 7.50
Switches, 3-way	3.00– 5.75	3.75– 6.50	4.50– 9.00
Switches, 4-way	3.75– 6.25	4.25– 7.50	5.00– 10.00
Fixture outlet (without fixture (wall or ceiling)	1.75– 4.50	2.50– 6.25	3.00– 8.25
Plugs (base and floor)	1.75– 4.00	2.50– 5.75	3.00– 6.50
Average electric outlet	2.50– 5.00	3.00– 7.00	3.75– 9.00
Electric bell (6 to 12 volt about):			
Electric bell or buzzer	1.50– 3.25	1.75– 3.75	2.50– 4.50
Bell or buzzer switch or push button	1.25– 2.50	1.50– 3.25	2.00– 3.75
Bell or buzzer transformer	2.25– 3.75	2.50– 5.00	3.00– 5.50

The cost per outlet varies considerably: \$2 and up for open work, about \$2.50 and up for knob and tube work, and \$3 and up for conduit work. At the present time, the average cost per outlet for conduit work in midwestern medium-sized cities is \$4 to \$8. When the number of outlets per room or per building is high, the cost per outlet is usually less than when the number of outlets is low.

To determine the number of outlets in a room or building, it is necessary to count all the floor and wall plugs, all the switches, and all the wall and ceiling light fixtures required. The total cost is equal to the estimated cost per outlet multiplied by the number of outlets. The costs of leads from transformer or from the electrical company's lines to the building, main switches, main fuse boxes, etc., must be included in the estimate as an extra item.

A more accurate approximate method is to list all the different kinds of outlets separately, and to use different prices for each kind of outlet and class of work. The outlets listed should include the meter outlet, main switches, fuse boxes, wall and ceiling fixture outlets, wall two-way, three-way, and four-way switches, and floor and base plugs. Each of these is called an outlet and is listed and priced accordingly. In addition, such items as doorbells, push buttons, and bell transformers are listed and priced. Approximate costs are given in Table 14-1. Costs of light fixtures are not included.

B. WIRING OR ROUGH ELECTRICAL WORK

6. Materials Take-off.—Before beginning the take-off, the estimator should make a careful study of the particular layout so that he may have a good general idea of the job. Sometimes the layout may be modified so as to save on the materials and labor or to improve the general wiring plan.

The materials take-off for the rough work is a complete list of all the materials required. The items included may be conduit, fittings, wire, outlet boxes, cut-out boxes, switches, plugs, fuse boxes, main switches, meter boards, knobs, tubes and nails, panel boards, and main switch and fuse boxes. Other items may be bells, buzzers, annunciators, bell transformers, dry batteries, push buttons, bell wire, etc. On some jobs there may be special items such as switchboards, large panel boards, dynamos, motors, and other electrical machinery. These special items should be included in the estimate for the rough work if installed at the time the rough wiring is done. If installed at the same time as the fixtures, these special items should be included in the finish estimate. Note if any of the special items require extra work such as foundations and insulation.

A satisfactory method is to begin at the entrance of the service wires or leads and list the service wires, switch, cabinet, panel board, meter board, cutout box, fuse box, etc. Then each floor of the building may be taken in order and all items on each floor listed. The estimator must include all vertical conduit and wiring between floors as well as the horizontal wiring. If desired, each room of each floor may be taken separately. Sometimes an estimator starts with a circuit as it leaves the main switch box, itemizes all materials connected with that circuit, and then takes all the remaining circuits in order. When going over the plans in this manner, it is necessary to measure or estimate the lengths of the circuits.

The use of specially devised blanks or forms are an aid in accurate estimating, as they tend to help the estimator to keep his details in a logical and orderly manner, and they also may be arranged to serve as a reminder list if all the various items are shown on them. Some estimators make a practice of using a good reminder list to help them in avoiding errors and omissions.

After the materials take-off is completed and checked, all the items may be priced, their costs estimated, and the totals found for the materials cost. Careful attention should be given to the buying so that the materials costs will be a minimum. It is often advisable to obtain prices from more than one firm. When computing the cost of any material, the cost of freight, insurance, drayage, breakage, waste, and handling should be included so as to obtain the materials cost delivered at the job.

7. **Materials.**—The wire used for electrical work is insulated copper wire of various diameters. The wire may be solid or stranded. Rubber insulated wire is used indoors, and weatherproof outdoors. There are many types of insulation suitable for different purposes. Two or more insulated wires may be woven or twisted together. A cable usually consists of two or more insulated wires in parallel and all covered with extra insulation.

The units for measuring wire are the foot for length, the mil or gage number for diameter, and the circular mil for area. A mil is 1/1,000 in. The circular mil is the area of a circle 1 mil in diameter. Table 14-2 gives information concerning insulated wires. Wires smaller than No. 12 or 14 should not be used for electric lighting and power rough work. Smaller wires are often satisfactory for bell and buzzer wiring. Wires may be either

solid or stranded. There are various types and kinds of armored wire and cable on the market, each cable usually containing two wires (sometimes one only and sometimes three or more). These cables are comparatively expensive, the price varying with the number and size of the wires and the insulation and armor.

TABLE 14-2.—INSULATED SOLID WIRES. DIAMETERS, AREAS, AND CARRYING CAPACITY

B & S gage number	Diameter solid wire, mils (1 mil = 0.001 in.)	Area, circular mils	Carrying capacity		Approximate price per 1,000 ft.	
			Rubber insulation, amperes	Other insulation, amperes	Rubber-covered indoor	Weather-proof outdoor
18	40.3	1,624	3	5	$4–$6	$4–$6
16	50.8	2,583	6	10	5– 6	5– 6
14	64.1	4,107	15	20	5– 7	6– 7
12	80.8	6,530	20	25	8– 10	8– 10
10	101.9	10,380	25	30	11– 15	10– 14
8	128.5	16,510	35	50	20– 25	14– 20
6	162.0	26,250	50	70	33– 40	21– 27
5	181.9	33,100	55	80		
					40– 50	30– 35
4	204.3	41,740	70	90	45– 60	40– 45
3	229.4	52,630	80	100	55– 70	50– 55
2	257.6	66,370	90	125	67– 85	60– 65
1	289.3	83,690	100	150		
0	325.0	105,500	125	200		
00	364.8	133,100	150	225		
000	409.6	167,800	175	275		
	447.2	200,000	200	300		
0000	460.0	211,600	225	325		

Wire is usually estimated in lineal feet with details such as size (gage), insulation, and solid or stranded noted. The allowance for waste, splicing, soldering, etc., may vary from about 5 to 10 per cent or so. Some estimators allow an extra foot for each outlet, 2 ft. for each main switch, and 3 to 5 ft. for each main circuit.

The conduit used may be rigid conduit, flexible conduit, flexible tubing, or armored cable. Rigid conduit is made of light galvanized steel pipe and may be heavy (outdoor and indoor) or light (indoor only). The heavy cannot be bent and requires threading and many fittings. The light rigid conduit can be bent and does not require threading. Flexible conduit is made of two spirally wound interlocking metal strips. Flexible tubing is made of fibrous materials. Flexible tubing is rarely used except with knob and tube work. Armored cable is like flexible conduit except that the conduit is made in place over the conductors (usually 2 or 3) so that both conduit and conductors can be installed together.

Conduit of various kinds is usually estimated in lineal feet, with diameter, kind, and other details being noted. The allowance for waste should be small, say 2 to 5 per cent.

Flexible tubing costs about $1 to $3 per 100 ft., and comes in about 7/32, 1/4, and 3/8 in. inside diameters.

TABLE 14-3.—ARMORED CABLE

Gage	14	14	12	12	10	8	8	6	6
Wires	2	3	2	3	2	2	3	2	3
Approx. price per 1,000 ft	$36	$54	$47	$65	$68	$120	$150	$195	$220

TABLE 14-4.—RIGID LIGHT-WEIGHT (THIN-WALL) CONDUIT AND FITTINGS

Item	Size, inches			
	1/2	3/4	1	1 1/4
	Approximate price per 100 ft. of conduit or 100 fittings			
Conduit (10-ft. lengths)	$ 5	$ 7	$ 9	$13
Couplings	11	15	23	40
Connectors	9	11	21	40
Adapters	5	8	12	20
Straps	2	4	5	7

Flexible conduit is usually available in the 1/2- and 3/4-in. trade sizes and may cost about $7 to $10 per 100 ft.

Tables 14-3 to 14-6 contain information in regard to armored cables, conduits and fittings. Prices of various electric-wiring materials are given in Table 14-7.

Attention is called to the fact that the prices given are approximate only, and for the year 1946. Prices will vary considerably from time to time. Prices will also vary with the make, grade, and quality of any article. Consequently, the estimator should secure the actual local prices in force at the time he is preparing the estimate.

TABLE 14-5.—RIGID HEAVY-WEIGHT CONDUIT AND FITTINGS

Item	Size, inches				
	½	¾	1	1¼	1½
	Approximate price per 100 ft. of conduit or 100 fittings				
Conduit (10-ft. lengths)	$ 9	$11	$17	$23	$30
Couplings	10	13	17	22	29
Elbows	23	29	46	58	75
Lock nuts	2	2	3	3	4
Bushings	2	3	4	5	6
Straps (malleable)	3	4	5	6	7
Straps (galvanized)	2	2	2	2	2
Entrance caps and L's	32	40	52	75	96

Rigid heavy-weight conduit is available in larger sizes up to 6 in. in diameter. Rigid heavy conduit up to about 1¼ in. may be bent to a fairly large radius (1 ft. or so) with suitable tools.

For special items for electrical rough work, the estimator should consult the local dealers and secure their prices.

For large pieces of apparatus, such as engines, generators, motors, and motor-generator sets, it is advisable to secure bids from the factory for the complete apparatus, delivered and erected, together with foundations, connected ready for service. If the prices of the apparatus are f.o.b. factory or nearest railway station, the estimator may estimate the cost of the apparatus installed on the job according to the method given in Chap. XVI on Heavy Machinery. In addition to the cost f.o.b. railway station, the estimator will have to estimate the cost of unloading

and transporting the apparatus to the site, erecting the apparatus on its foundations, lining up, and making all necessary wiring connections. In some cases, the cost of building the foundations will need to be included. Often the factory may provide the electrical machine and the contractor who installs it must provide the wiring materials, switches, fuses, switchboard panels, etc., as well as furnishing all labor required for the complete installation with machine ready to run.

TABLE 14-6.—NUMBER OF WIRES AND MINIMUM SIZE OF CONDUIT

Size of wire B & S gage	Number of wires in one circuit								
	1	2	3	4	5	6	7	8	9
	Minimum size of conduit, inches								
14	½	½	½	¾	¾	1	1	1	1
12	½	½	¾	¾	¾	1	1	1	1¼
10	½	¾	¾	1	1	1	1¼	1¼	1¼
8	½	¾	1	1	1	1¼	1¼	1¼	1½
6	½	1	1¼	1¼	1½	1½	2	2	2
5	¾	1¼	1¼	1¼	1½	2	2	2	2
4	¾	1¼	1¼	1½	2	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1¼	1½	1½	2	2	2½	2½	2½
1	¾	1½	1½	2	2	2½	2½	3	3
0	1	2	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1¼	2	2½	2½	3	3	3½	3½	4

8. Labor.—The labor of electrical wiring or rough work is performed by electricians with or without the help of apprentices or helpers. A team of two electricians, or of one electrician and one helper, is a good working combination, especially on small jobs. Medium-sized and large jobs may require several electricians and helpers working under the direction of a foreman.

The labor required per outlet or for a certain item of work will vary with the type of work, the working conditions, and the skill and inclination of the workers. The amount of time required

TABLE 14-7.—VARIOUS ELECTRIC WIRING MATERIALS AND APPROXIMATE 1946 PRICES

Item	Price
Main switches, up to 60 amp., each	$2–$7
Fuse cabinets, 60 amp. or less, each	2– 7
Combination main switch and fuse cabinets, 60 amp. or less, each	3–12
Fuse cutout boxes, each	1– 2
Outlet, switch, receptacle, boxes, galvanized, per 100	10–12
Outlet box covers, galvanized, per 100	3– 6
Outlet boxes with brackets, galvanized, per 100	15–20
Porcelain outlet boxes, per 100	15–20
Porcelain outlet box covers, per 100	8–10
Switches, toggle, 2-way, per 100	10–30
Switches, toggle, 3- and 4-way, per 100	15–60
Switches, push button, 2-way, per 100	10–45
Switches, push button, 3- and 4-way, per 100	15–75
Convenience outlets, single and duplex, per 100	9–25
Bar hangers, per 100	8–12
Fuses, round glass, 10 to 30 amp., per 100	4– 6
Fuses, cartridge, 15 to 30 amp., per 100	4– 6
Fuses, cartridge, 35 to 60 amp., per 100	8–12
Glazed split knobs, per 100	1– 2
Tubes, per 100	1– 2
Cleats, 2 wire, per 100 pair	2– 3
Flexible loom 7/32 in., 100 ft	1– 2
Receptacles and drop-cord cleats, per 100	7–15
Brackets, oak, per 100	3– 4
Bracket insulators, per 100	6– 8
Service insulators, per 100	10–16
Friction and rubber tape, 100 oz	2– 3
Bell, buzzer, annunciator wire, per M ft	2– 4
Bell transformers	1– 3
Bells and buzzers, per 10	2– 8
Push button, per 10	1– 2

for the rough work per outlet may vary from less than 1 hr. to 3 or 4 hr. The labor per outlet will vary with the kind of wiring, being least with armored cable and knob and tube work and greatest with heavy rigid conduit work. The labor will also vary with the size of conduit and the size of the wires, the larger sizes requiring more labor per 100 ft.

The approximate labor-hours required per outlet are given in Table 14-8.

TABLE 14-8.—APPROXIMATE LABOR-HOURS FOR INSTALLING AN OUTLET IN ROUGH ELECTRICAL WORK

Kind of Work Installed	Labor-hours per Outlet
Knob and tube wiring. Nos. 14, 12, and 10 gage wire	0.7–2.0
Armored cable and fittings, Nos. 14, 12, and 10 gage wire	0.8–2.0
Flexible conduit, and wire, ½ and ¾ in.	0.8–2.0
Light-weight conduit, fittings, and wire, ½ and ¾ in.	1.0–2.0
1 and 1¼ in.	1.1–2.2
Heavy-weight rigid conduit, fittings, and wire, ½ and ¾ in.	1.2–2.3
1 and 1¼ in.	1.2–2.5
1½ and 2 in.	1.3–2.7
2½ and 3 in.	1.3–3.0

TABLE 14-9.—APPROXIMATE LABOR-HOURS FOR INSTALLING CONDUIT, CABLE, AND WIRE

Conduit and wire	Labor-hours per 100 ft.	Conduit and wire	Labor-hours per 100 ft.
Installing heavy rigid conduit, and fittings, including outlet boxes:		Pulling and installing wire in conduit:	
½ and ¾ in.	10– 18	Nos. 18 and 16 gage	0.8–1.5
1 and 1¼ in.	14– 22	14 and 12 gage	1.0–1.8
1½ in.	18– 27	10 and 8 gage	1.5–2.5
2 in.	24– 35	6 gage	2.2–3.5
2½ in.	30– 44	4 gage	2.8–4.5
3 in.	38– 56	3 gage	3.5–5.5
4 in.	48– 70	2 gage	4.5–6.5
5 in.	60– 90	1 gage	5.5–7.5
6 in.	75–110	Tube and knob work, installing wire and tubes and knobs:	
Installing light-weight conduit and fittings, including outlet boxes:		No. 14, 12, and 10 gage wire	4–12
½ and ¾ in.	7– 12	Installing amored cable and fittings:	
1 and 1¼ in.	9– 16	No. 14, 12, and 10 gage wire	6–14
Installing flexible conduit and fittings:			
½ and ¾ in.	6– 10		

Conduit fittings do not include main switch and fuse boxes, cabinets, etc.

Note that any one of the larger sizes of rigid conduit will usually carry wires for more than one outlet. Consequently, the labor-hours per outlet will not vary appreciably with the size of rigid conduit.

The approximate labor-hours for installing various items of rough electrical work are given in Table 14-9. The labor values given for installing conduit includes all labor for fittings such as threading pipe, making joints, and installing outlet boxes for wall and ceiling fixtures, switches, and for floor and base plugs, but not for pulling wire. The labor values given for wire pulling include the labor required for pulling the wire through the conduit and for soldering and taping ends in outlet boxes.

TABLE 14-10.—APPROXIMATE LABOR-HOURS FOR INSTALLING VARIOUS ITEMS IN ROUGH ELECTRICAL WORK

Item Installed	Labor-hours each
Meter	0.5 –1.0
Main switch and box (up to 60 amp.)	0.8 –2.0
Fuse box (60 amp. or less)	0.5 –1.2
Combined switch and fuse box (60 amp. or less)	1.0 –2.5
Cabinet (60 amp. or less)	1.0 –3.0
Making conductor connections, as in a cabinet	0.2 –0.4
Outlet boxes, for ceiling and wall fixtures	0.2 –0.4
for service switches, floor and base plugs	0.15–0.3

Small service switches, floor and base plugs, and their covers and plates are usually installed with the finish work.

The wages of electricians vary considerably at different times and in different parts of the United States. They may range from \$1.25 to \$2 per hour with an average (1946) of about \$1.25 to \$1.75 per hour. Wages of helpers will be about half those of electricians, and will range from about \$0.65 to \$1.50 per hour.

Diagrams 14-1, 14-2, and 14-3 (pages 633, 634, and 635) may be used for estimating labor costs of rough electrical work and wiring per outlet (Table 14-8), per item (Table 14-10), per 100 ft. of conduit (Table 14-9), per 100 ft. of wire (Table 14-9), and for various other items when the hourly wage is known and the hourly labor output may be reasonably assumed.

9. Equipment.—The equipment required for rough electrical work will vary with the type of work. Heavy rigid conduit work will require pipe cutters, hack saws, threading tools, reamers, and other small tools needed for conduit work. Light

rigid conduit work, which can be bent and which does not require threading, will not require threading tools. Other *small tools* needed will include hand and electric drills, saws, hammers, chisels, gasoline torches, soldering outfits, fishing wire, pliers, and hand lines. Many firms also include tape and solder with the equipment. Ladders, stepladders, sawhorses and planks may be needed for scaffolding.

The cost of equipment for a team of two men will vary with the size of the job and the amount of work required. About $5 to $20 per team per job should be sufficient, including transportation.

10. Overhead and Profit.—The general overhead for rough electrical work may range from about 10 to 20 per cent of the sum of materials, labor, and equipment costs. When based on labor costs alone, the percentage may range from about 15 to 30 per cent. Workmen's compensation insurance, social-security tax, etc., costs are in addition to the percentages given. Compensation insurance may vary from about 2 to 6 per cent of the total pay roll.

Total overhead expenses may be expected to range from about 20 to 35 per cent when based on labor costs alone, and from about 15 to 25 per cent when based on the sum of materials, labor, and equipment.

The profit charged on rough electrical work may range from about 6 to 15 per cent of the sum of all other costs. However, if the contractor has estimated the costs of the materials at retail prices including their overhead and profit, profit on these items should not be included again.

11. Summary.—The estimate for wiring or for rough electrical work may be summarized to show total costs of materials, labor, equipment, overhead, and profit and also to show unit costs per outlet. Sometimes the estimator computes the cost per 100 ft. of conduit or per 100 ft. of circuit as units. The summary may be as follows:

Item	Cost per Outlet	Total Cost
Materials....................	$	$
Labor........................		
Equipment....................		
Overhead.....................		
Profit.......		
Total........................	$	$

12. Illustrative Estimate.—Prepare an approximate estimate for the rough wiring for a new residence, and compute the estimated cost per outlet. The local electric company supplies the leads from the transformer to the house and supplies and installs the meter. There are to be 26 ceiling outlets, 14 wall outlets, 24 service switches, and 30 base plugs, giving a total of 94 outlets.

The materials take-off gave the following information:

1 main switch and cutout box	=	$ 4.00
3 small fuse boxes, at $1	=	3.00
32 outlet boxes with covers, at $0.15	=	4.80
94 switch, base plug, and receptacle boxes at $0.10	=	9.40
60 ft., ¾-in. thin-wall conduit (light weight) at $9 per 100 ft.	=	5.40
fittings for ¾-in. light-weight conduit, estimated	=	2.00
720 ft., ½-in. light-weight conduit at $7 per 100 ft.	=	50.40
fittings for ½-in. light-weight conduit, estimated	=	15.00
60 ft., ½-in. flexible conduit at $8 per 100 ft.	=	4.80
fittings for ½-in. flexible conduit, estimated	=	1.20
65 ft., No. 8 rubber-covered wire at $2.20 per 100 ft.	=	1.45
65 ft., No. 10 rubber-covered wire at $1.30 per 100 ft.	=	0.85
1,700 ft., No. 12 rubber-covered wire at $1.00 per 100 ft.	=	17.00
Miscellaneous materials, estimate for job	=	6.70
Total materials	=	$126.00

The labor-hours required will be about as follows:

Installing main switch and cutout box	=	1.3 hr.
Installing 3 small fuse boxes	=	3.0 hr.
Installing 60 ft. of ¾-in. light-weight conduit and fittings	=	9.0 hr.
Installing 720 ft. of ½-in. light-weight conduit and fittings	=	80.0 hr.
Installing 60 ft. of ½ in. flexible conduit	=	3.0 hr.
Pulling 65 ft. of No. 8 wire	=	1.0 hr.
Pulling 65 ft. No. 10 wire	=	1.0 hr.
Pulling 1,700 ft. of No. 12 wire	=	24.5 hr.
Total labor-hours	=	122.8 hr.
Labor costs with electricians at $1.65 per hour	=	$203.00
Equipment cost for job, estimated	=	12.00
Overhead cost at 27 per cent of labor cost	=	55.00
Profit at 10 per cent of all other costs	=	40.00
Total estimated cost of rough electrical work	=	$436.00

This estimate may be summarized and unit costs computed on a basis of 94 outlets as follows:

Item	Cost per Outlet	Total Cost
Materials	$1.34	$126
Labor	2.16	203
Equipment	0.13	12
Overhead	0.59	55
Profit	0.43	40
Total	$4.65	$436

C. FINISH ELECTRICAL WORK

13. Materials and Materials Take-off.—The materials usually included in finish electrical work are ceiling fixtures, wall brackets and fixtures, service switches and plates, floor- and base-plug receptacles and plates. Ceiling and wall fixtures and brackets are usually selected by the owner. The price of a fixture may vary from about $1 to several hundred dollars. The cost of wall brackets may vary from $1 up to $20 or $25.

Service switches, service receptacles, and plates are comparatively inexpensive. Service receptacles and switches (two way) without cover plates may cost about $0.10 to $0.50 each for ordinary types. Three-way and four-way service switches without cover plates may cost $0.20 to $1.00 each. Convenience outlets, single and duplex, may cost about $0.10 to $0.35 each without cover plates. Cover plates may cost about $0.10 and up depending on material, style, finish, etc.

There are a great variety of rosettes, receptacles, sockets, covers, etc., on the market. Prices range from about $0.10 and up for each.

Lamp sockets of various types will cost about $0.15 up to about $0.80 for ordinary types.

Drop cord, lamp cord, fixture cord, etc., come in various styles, coverings, and covers. Prices range from about $1.50 to $4 per 100 ft. Most cord contains two stranded copper wires of No. 18 gage, though cord containing larger wire (No. 16 or 14 gage) is available at slightly higher prices.

Fixture wire, insulated, No. 18 gage, costs about $1.50 per 100 ft. The No. 16 gage costs a little more.

Please note that prices given for materials are approximate prices for 1946. Prices used in actual estimates should be obtained from dealers' catalogues.

The materials take-off for finish electrical work should list each item of ceiling fixtures, wall fixtures and brackets, service switches with plates, plugs and other receptacles with plates, rosettes, covers, drop cord, sockets, etc. Finish, style, catalogue numbers, and other details should be noted that will aid in pricing the various items.

14. Labor.—The labor required for installing fixtures will vary somewhat depending on the size of the fixture, working conditions, and skill of the electrician. Most fixtures come ready wired so

that the installing consists of installing the fixture in place and connecting the fixture wires to the circuit wires. Sometimes the fixture must be wired, and labor and materials furnished for this work.

Table 14-11 gives approximate labor-hours required for installing various types of fixtures, switches, plugs, and service receptables ready for operation.

TABLE 14-11.—APPROXIMATE LABOR-HOURS REQUIRED FOR INSTALLING ELECTRIC FIXTURES

Item	Labor-hours each	Item	Labor-hours each
Wall light or bracket (one or two lights)	0.20–0.40	Rosette with drop cord and socket	0.15–0.40
Ceiling fixture (one or two lights)	0.25–0.50	Two-way service switch	0.10–0.25
Ceiling fixture (three, four, or five lights)	0.30–0.75	Three-way service switch	0.20–0.50
Wiring fixtures in addition (per light or per socket)	0.10–0.25	Four-way service switch	0.25–0.75
		Base- or floor-plug outlet (cover plates included)	0.10–0.25

Labor wages for electricians vary from about $1.25 to $2 per hour with averages of $1.25 to $1.75 per hour in the United States for the year 1946. Helper's hourly wages are about half those of the electricians.

Diagrams 14-4 (page 636) may be used for estimating the labor costs of finish electrical work when the labor wage per hour is known and the labor output may be reasonably assumed.

15. Equipment.—The equipment required for installing fixtures will include the electrician's ordinary hand tools with tape and small soldering outfit. Stepladders may be needed for installing ceiling and high wall fixtures. The cost of equipment for an ordinary installation job may range from $3 or $4 up to about $15 or so for each pair of electricians depending upon the work and magnitude of the job.

16. Overhead and Profit.—Overhead costs for finish electrical work are usually based on labor costs. The percentage may range from 15 to 25 for ordinary overhead plus percentages for workmen's compensation insurance, social security, etc. Total overhead may range from 20 to 35 per cent of all labor costs.

Prices of materials for finish electrical work are usually retail prices and include all shop overhead and profit. If the prices do not include shop overhead and profit, these cost items must not be omitted. Shop overhead on fixtures, etc., may vary from 10 to 20 per cent of the cost.

The profit on finish electrical work may range from about 8 to 20 per cent of the costs of labor, equipment, and labor overhead. Shop profit on fixtures, etc., may range from 10 to 50 per cent. This profit is usually included in the retail price.

17. Summary.—The estimates for finish electrical work may be tabulated to show total costs and costs per outlet. The material costs per outlet may not have much significance because of the variation in the prices of the fixtures. The prices of the service switches and service outlets do not vary so much. Labor, equipment, and overhead costs per outlet are worth computing.

The estimate may be tabulated as follows. If desired, the materials costs may be divided by separating the fixture costs from the other material costs.

Item	Cost per Outlet	Total Cost
Materials....................	$	$
Labor........................		
Equipment....................		
Overhead.....................		
Profit.......................		
Total........................	$	$

18. Illustrative Estimate.—Prepare an approximate estimate for furnishing and installing all fixtures, service switches, service outlets, etc., for the new residence for which the wiring or rough electrical work was estimated in Art. 12 of this chapter. It is assumed that the owner has selected the fixtures listed from the dealer's shop and that the price of the fixture includes all shop overhead and profit.

Materials take-off and cost:

Basement:		
3 switches with plates	at $ 0.35 =	$ 1.05
5 drop lights with rosette, cord and sockets	at $ 1.00 =	5.00
First floor:		
3 five-light ceiling fixtures	at $11.00 =	33.00
1 three-light ceiling fixture	at $ 6.25 =	6.25
4 one-light ceiling fixtures	at $ 2.50 =	10.00
5 small one-light ceiling fixtures	at $ 1.60 =	8.00
14 wall brackets	at $ 2.00 =	28.00

11 switches with plates	at \$ 0.40 =	4.40
1 three-way switch with plate	at \$ 0.60 =	0.60
20 base plugs with plates	at \$ 0.40 =	8.00
Second floor:		
7 one-light ceiling fixtures	at \$ 2.25 =	15.75
5 switches with plates	at \$ 0.40 =	2.00
1 three-way switch with plate	at \$ 0.60 =	0.60
10 base plugs with plates	at \$ 0.40 =	4.00
Attic:		
1 switch	at \$ 0.35 =	0.35
1 rosette with socket	at \$ 1.00 =	1.00
Total cost of all fixtures	=	\$128.00

Labor cost of installations. For purposes of installation the various fixtures may be grouped as follows:

4 five- and three-light ceiling fixtures at 0.5 hr.	=	2.0 hr.
16 one-light ceiling fixtures at 0.35 hr.	=	5.6 hr.
6 rosette, drop cord, and socket ceiling fixtures at 0.25 hr.	=	1.5 hr.
14 wall brackets at 0.25 hr.	=	3.5 hr.
2 three-way switches at 0.35 hr.	=	0.7 hr.
22 switches at 0.15 hr.	=	3.3 hr.
30 base plugs at 0.15 hr.	=	4.5 hr.
94 total, for a check	Total =	21.1 hr.

Labor costs, say 21 hr. at \$1.65 per hour	=	\$ 35.00
Equipment, say \$5	=	5.00
Overhead, at 27 per cent of labor costs	=	9.00
Profit, at 10 per cent of all other costs except materials	=	5.00
(Shop overhead and profit is included in prices of fixtures.)		
Total estimated cost	=	\$182.00

This estimate may be summarized and unit costs computed on a basis of 94 outlets as follows:

Item	Cost per Outlet	Total Cost
Materials	\$1.37	\$128
Labor	0.37	35
Equipment	0.05	5
Overhead	0.10	9
Profit	0.05	5
Total	\$1.94	\$182

C. TOTAL OR COMBINED ELECTRICAL ESTIMATES

19. Combined Electrical Estimates.—On some jobs, the electrical contractor estimates both the rough and finish work and submits a bid for the entire job. When preparing an estimate for the complete job, the estimator usually estimates the rough

and finish work separately and then adds the two estimates to find the costs of the complete or combined work.

20. Illustrative Estimate.—For an example of an estimate for a combined or complete electrical job, the following tabulation has been prepared, using the estimated costs found in the preceding estimates for rough and finish work. Note that the shop overhead and profits on fixtures are included in the material costs.

Item	Wiring or rough work	Fixtures or finish work	Total
Materials	$126.00	$128.00	$254.00
Labor	203.00	35.00	238.00
Equipment	12.00	5.00	17.00
Overhead	55.00	9.00	64.00
Profit	40.00	5.00	45.00
Total	$436.00	$182.00	$618.00
Cost per outlet (94 outlets)	$ 4.65	$ 1.94	$ 6.59

Note that if the costs of the lighting fixtures (for ceiling and wall lights) are deducted, the cost per outlet will be approximately $5.50.

CHAPTER XV

PAINTING, PAPERING, AND GLAZING

A. PAINTING

1. Painting.—The cost of painting will depend in general upon the kind of surface (wood, steel, plaster) to be painted, the form of surface (flat, grooved, paneled, etc.), the kind of paint used, the number of coats, the particular coat (priming, second, finish, etc.), and the skill and inclination of the workmen.

Painting is usually estimated by units of area of 1 sq. ft., 1 sq. yd., or 1 square (100 sq. ft.). The unit of one square seems to be the most practical and popular.

Surfaces that may have varying unit costs should be taken off separately. When listing doors and windows, no deductions should be made for the glass, as the extra labor cost of painting the narrow strips is often more than the saving in paint. It is customary to consider each linear foot of wood trim as 1 sq. ft., because there is but little difference in the time required to paint trim 1 ft. wide or less.

The kind of surface (wood, metal, plaster, etc.) should always be noted. The nature of the surface is important because the spreading capacity of any paint, varnish, or enamel varies, and the amount of labor required also varies, for different kinds of surfaces.

The amount of paint used on any given surface will also depend on how thoroughly the paint is brushed in. Consequently, there will be a variation in the amount of paint that will be used by different painters to cover a given surface.

The following procedure for the take-off is recommended. The number of coats and the kinds of coats (priming, second, finish, size, filler, etc.) should be noted. Many estimators prefer to divide the painting into exterior and interior work.

Exterior work.

Walls and siding, area in square feet.

Trim, length in lineal feet, with width noted.

Doors by total areas in square feet.
Windows by number and kind and total areas in square feet.
Blinds by number and areas in square feet.
Cornice, length in lineal feet, with girth noted.
Balusters and posts, by number of pieces, or length in lineal feet.
Shingles by square feet of shingled area when paint is applied by a brush, or by number of shingles when dipped.
Steel or iron roofing, by area in square feet.

Interior work.

Wall and ceiling surfaces in square feet, noting kind of surface and treatment required.
Floor surface in square feet with treatment noted.
Interior trim by length in linear feet with width noted.
Stair rails (posts, rails, balusters) by number of pieces or length in linear feet.
Doors by number, kind, and total areas in square feet.
Windows by number, kind, and total areas in square feet.
Piping by length in lineal feet.
Radiators by square feet of radiation.

Structural-steel work.

By tonnage or area, noting kinds and approximate sizes of members, such as columns, beams, girders, and purlins and of small, medium, and large sizes.

When estimating the number of square feet of surface area per ton of structural steel, the following approximations may be used:

	Sq. Ft. per Ton
Small members, beams, column purlins, etc.	350–450
Medium members	250–350
Large members	175–250
Small trusses and built-up frames	350–450

2. Materials.—The paint specified may be a brand of ready-mixed paint, or the contractor may be required to mix the paint at his shop, using different materials in certain proportions. In many instances, the ready-mixed paints need to be thinned on the job. Hence, the materials required may include ready-mixed paint, linseed oil, turpentine, varnish, shellac, putty, oil, and drier.

Exterior paint	\$2.00–\$4.00 per gallon
Boiled linseed oil	0.90– 1.50 per gallon
Turpentine	0.45– 1.00 per gallon
Drier (Japan)	0.35– 0.80 per quart
Putty	0.05– 0.10 per pound
Enamel	2.00– 5.00 per gallon
Varnish	2.75– 5.00 per gallon
Shellac	1.25– 3.00 per gallon
Gloss and flat paint, interior	2.00– 4.00 per gallon
Wood paste filler	0.12– 0.25 per pound
Wall primer	1.75– 3.00 per gallon
Calcimine	0.40– 1.00 per gallon
Calcimine, washable	0.08– 0.15 per pound
Calcimine, regular	0.06– 0.10 per pound
Patch plaster	0.05– 0.10 per pound
Calcimine (Kalsomine) size	0.20– 0.35 per pound
Dye stain	2.00– 3.50 per gallon
Oil stain	1.80– 3.25 per gallon
Zinc sulphate	0.20– 0.35 per pound
Cold-water paint	0.07– 0.15 per pound
Aluminum paint	2.25– 4.00 per gallon
Graphite paint	1.30– 3.00 per gallon
Ferric oxide paint	1.50– 3.00 per gallon
Red lead, dry	0.10– 0.15 per pound
White lead, in oil	0.14– 0.20 per pound

For calcimine, 5 lb. of material and 2 quarts of water will make 1 gal. One pound of calcimine size will make ½ to ¾ gal. Paste wood filler if bought in pounds requires about 5 lb. per 250 or 300 sq. ft. Three pounds of zinc sulphate are mixed with 1 gal. of water. Five pounds of cold-water paint are used per gallon of water.

3. Labor.—The labor-hours required to apply a coat of paint to 100 sq. ft. of surface will depend upon the surface, the paint, the weather, the location of the surface (floor wall, high ceiling, etc.), and the skill and inclination of the workman.

Exterior painting should not be done in damp or wet weather. Interior painting may be done in damp or wet weather when required, provided that the surfaces may be kept clean and dry. Painting should not be done in very cold and freezing weather. However, interior painting may be done in cold weather if artificial heat is provided. The surface painted per hour per man may vary from 20 to 200 sq. ft. (0.50 to 5.00 hr. per 100 sq. ft.). Consequently, in order to arrive at a fair labor estimate, the estimator must know his workmen and must analyze care-

TABLE 15-3.—APPROXIMATE COVERING CAPACITY OF PAINTING MATERIALS
Gallons per 100 sq. ft. for one coat

Painting material	Metal, any coat	Wood		Plaster, brick cement, and stucco	
		First coat	Other coat	First coat	Other coat
White lead and oil	0.20–0.25	0.25–0.35	0.20–0.25	0.35–0.50	0.20–0.35
Zinc white and oil	0.17–0.20	0.20–0.25	0.17–0.20	0.30–0.40	0.17–0.25
Good ready-mixed paint (exterior)	0.17–0.20	0.20–0.25	0.17–0.20	0.25–0.35	0.17–0.25
Enamel	0.17–0.20	0.20–0.25	0.17–0.20	0.22–0.30	0.17–0.25
Floor enamel	....	0.17–0.25	0.14–0.20	0.18–0.25	0.14–0.20
Interior flat paint	....	0.20–0.25	0.17–0.20	0.22–0.35	0.18–0.25
Interior gloss paint	....	0.30–0.40	0.22–0.35	0.35–0.50	0.25–0.35
Varnish	0.17–0.20	0.20–0.25	0.17–0.20	0.22–0.30	0.17–0.25
Shellac	....	0.14–0.17	....	0.17–0.25	
Stain	....	0.20–0.35			
Wood paste filler	....	0.30–0.40			
Wall primer	....	....	....	0.20–0.35	
Glue size	....	0.20–0.35	....	0.20–0.35	
Varnish size	....	0.20–0.35	....	0.20–0.35	
Zinc sulphate	....	....	....	0.25–0.50	
Calcimine (Kalsomine)	....	....	....	0.25–0.50	
Cold-water paint	....	0.30–0.50	....	0.35–0.50	

fully all details of the job. Labor wages for painters may vary from $1 to $2 per hour, depending upon time, locality and men available. From $1.20 to $1.50 is an average variation.

Table 15-4 gives the approximate labor required for painting various surfaces. The values given are for good workmen working under good conditions and on work that is not difficult.

The labor required for painting structural steel, one coat, is approximately as follows:

	Hours per Ton
Heavy-weight members	0.5–0.9
Medium-weight members	0.7–1.4
Light-weight members	1.0–2.0
Small trusses and built-up frames	1.0–2.0

Diagram 15-2 (page 638) may be used for finding labor costs per 100 sq. ft. of surface (or 100 lin. ft.) for painting with one coat

TABLE 15-4.—APPROXIMATE LABOR REQUIRED FOR PAINTING DIFFERENT SURFACES

Kind of work	Square feet per hour for one coat	Hours per 100 sq. ft. for one coat
Exterior work:		
Walls, siding and shingles	150–200	0.50–0.70
Doors, windows, blinds	120–180	0.55–0.85
Steel or iron roofing	160–220	0.45–0.65
Trim, cornice, water table, balusters, posts, rails, etc. (in lineal feet)	100–180	0.85–1.00
Stucco	120–150	0.65–0.85
Interior work:		
Trim, filling and puttying (all trim in lineal feet)	60– 90	1.10–1.65
Staining	140–200	0.50–0.70
Shellacing	120–180	0.55–0.85
Sand papering	60– 90	1.10–1.65
Rubbing	60– 90	1.10–1.65
Varnishing	120–180	0.55–0.85
Flat painting	120–180	0.55–0.85
Enameling	100–150	0.65–1.00
Floors, filling and puttying	120–180	0.55–0.85
Staining	150–200	0.50–0.65
Shellacing	150–200	0.50–0.65
Varnishing	140–200	0.50–0.70
Waxing	150–200	0.50–0.65
Polishing	100–150	0.65–1.00
Sanding (hand)	40– 80	1.25–2.50
Sanding (machine)	100–200	0.50–1.00
Plaster walls and ceilings, sizing	200–250	0.40–0.50
Calcimining	200–250	0.40–0.50
Painting	120–160	0.60–0.85
Stenciling (in lineal feet)	15– 30	3.35–6.65
Brick and concrete work, oiling, sizing, sulphating, etc.	120–180	0.55–0.85
Painting	120–150	0.65–0.85
Structural-steel work	150–200	0.50–0.65

when the labor wage is known and the labor output may be reasonably assumed.

Diagram 15-3 (page 639) may be used for finding labor costs of painting structural steel.

4. **Equipment.**—The equipment used on a painting job will include brushes and hand tools, ladders, planks, and light,

movable scaffolding. When a built-up scaffold is required, this should be estimated separately in regard to materials and carpenters' time. The cost of sanding, rubbing, and cleaning materials is usually included with the equipment costs. If an electric sander or polisher is used, the cost of these machines (rental, depreciation, maintenance, power, transportation, etc.) should be included.

The cost of ladders, light scaffolding, brushes, and small tools (including transportation) may vary from about $10 to $30 for a comparatively small job or per gang of three to five painters. When special scaffolding is required, this cost will be increased considerably. In some cases, the cost of a built-up scaffold may be equal to the cost of applying one coat of paint.

5. Overhead and Profit.—Overhead charges for painting are usually based on labor costs, but may be based on the sum of labor and material costs. When based on labor costs alone, the percentage for overhead may vary from about 25 to 45 per cent for ordinary interior and exterior work on buildings. The percentage may vary from 15 to 25 per cent when based on the sum of material and labor costs. For painting structural steel after erection, the overhead may vary from 50 to 80 per cent of the labor costs or from 30 to 50 per cent of the costs of labor and material.

Profit may range from about 8 to 15 per cent of all other costs for ordinary painting jobs, and from 10 per cent and up for structural-steel jobs.

6. Painting Estimates.—The estimate for a complete painting job should include the following:

Materials. Paint, putty, oil, turpentine, size, varnish, shellac, etc.

Labor. All painters. Also foremen, helpers, apprentices, if any.

Equipment. All equipment costs.

Overhead. Based on labor costs or on sum of material and labor costs.

Profit.

The summary or tabulation should show unit costs per 100 sq. ft. (or per 100 lin. ft. for trim) as well as total costs.

7. Illustrative Estimate.—Prepare a complete estimate for the interior paint job for a new six-room house. A study of the plans and specifications shows the following:

First Floor	Second Floor
2 outside doors	8 inside doors
4 inside doors	8 single windows
4 double windows	600-ft. trim
4 single windows (2 in kitchen)	700 sq. ft. flooring
440-ft. trim (42-ft. kitchen)	1 stairs
700 sq. ft. flooring	1 medicine cabinet
1 stairs	1 linen closet
1 mantel	1 towel closet
1 broom closet	
2 kitchen cupboards	

All floors to be sanded, filled, and given 3 coats varnish
First-floor doors and windows and trim, stain, sandpapered, and 2 coats varnish; except kitchen which is to have prime coat, 2 flat coats, and 2 enamel.
First-floor stairs same as floor and trim.
First-floor walls and ceiling, 1 coat sizing and 2 coats flat oil paint.
Kitchen equipment and mantel are finished at mill.
Second-floor doors and windows and trim, 1 coat primer, 2 coats flat and 2 coats enamel.
Second-floor stairs, stained and varnished as floors.
Second-floor walls and ceilings left as they are.
Medicine cabinet, towel closet, and linen closet finished at mill.
Prices of materials are as follows:

Floor paste	$0.16 per pound
Floor varnish	$3.20 per gallon
Stain, oil	$2.10 per gallon
Trim varnish	$3.20 per gallon
Wall sizing (prime)	$1.90 per gallon
Wall paint	$1.65 per gallon
Trim, flat paint	$1.85 per gallon
Trim, enamel	$2.80 per gallon
Materials for sanding	$2.20 for job

Floor sander, rental charge, $1.50 per day plus $2 transportation.
Wages of painters, $1.10 per hour.
Allowance for other equipment for job, $18.
Overhead, 31 per cent of labor costs.
Profit, 10 per cent of all other costs.
Solution: Materials.

Perhaps the simplest way is to consider the different items.

Floors, 1,400 sq. ft.

Paste, 1 coat, at 0.35 gal. per 100 sq. ft. $= 4.90$ gal.

Varnish, 3 coats at 0.20 gal. per 100 $= 3 \times 14 \times 0.20 = 8.40$ gal.

Stairs ($72 + 60 = 132$ sq. ft.)

Paste, 1 coat at 0.35 gal. $= 0.47$ gal.

Varnish, 3 coats at 0.20 gal. $= 0.80$ gal.

Stair rails and balusters (50 lin. ft.)
  Stain 1 coat at 0.25 gal. per 100 lin. ft. = 0.13 gal.
  Varnish 2 coats at 0.20 gal. per 100 lin. ft. = 0.20 gal.
First-floor trim (less kitchen) (398 lin. ft.)
  Stain, 1 coat at 0.25 gal. = 1.00 gal.
  Varnish, 2 coats at 0.20 gal. = 1.60 gal.
First-floor doors, finish, 2 on one side, 3 on two sides (say 250 sq. ft.)
  Stain, 1 coat at 0.25 gal. = 0.63 gal.
  Varnish, 2 coats at 0.20 gal. = 1.00 gal.
First-floor windows, 4 double on one side, 2 single on one side (230 sq. ft.)
  Stain, 1 coat at 0.25 gal. = 0.58 gal.
  Varnish, 2 coats at 0.20 gal. = 0.92 gal.
First-floor kitchen doors, 2 on one side (65 sq. ft.)
  Flat paint, 3 coats at 0.20 gal. = 0.40 gal.
  Enamel paint, 2 coats at 0.25 gal. = 0.35 gal.
First-floor kitchen windows, 2 single on one side (50 sq. ft.)
  Flat paint, 3 coats at 0.20 gal. = 0.30 gal.
  Enamel paint, 2 coats at 0.25 gal. = 0.25 gal.
First-floor kitchen trim, 42 lin. ft.
  Flat paint, 3 coats at 0.20 gal. = 0.25 gal.
  Enamel paint, 2 coats at 0.25 gal. = 0.20 gal.
First-floor walls and ceilings (1,680 + 700 = 2,380 sq. ft.)
  Sizing (wall prime), 1 coat, at 0.25 gal. = 6.00 gal.
  Flat paint, 2 coats, at 0.30 gal. = 14.30 gal.
Second-floor trim, 600 lin. ft.
  Flat paint, 3 coats at 0.20 gal. = 3.60 gal.
  Enamel paint, 2 coats at 0.25 gal. = 3.00 gal.
Second-floor doors, 8 on two sides (250 sq. ft.)
  Flat paint, 3 coats at 0.20 gal. = 1.50 gal.
  Enamel paint, 2 coats at 0.25 gal. = 1.25 gal.
Second-floor windows, 8 single on one side (200 sq. ft.)
  Flat paint, 3 coats at 0.20 gal. = 1.20 gal.
  Enamel paint, 2 coats at 0.25 gal. = 1.00 gal.

Materials summary:

Floor paste, 5.37 gal., say 5.5 gal. at 5 lb. per gal. at $0.16	=	$ 4.40
Floor varnish, 9.20 gal., say 9.25 gal. at $3.20	=	29.60
Trim, door, and window stain, 2.34 gal., say 2.50 gal. at $2.10	=	5.25
Trim, door, and window varnish, 3.72 gal., say 3.75 gal. at $3.20	=	12.00
Trim, door, and window flat paint, 7.25 gal. at $1.85	=	13.40
Trim, door and window enamel, 6.05 gal., at $2.80	=	16.95
Wall size or prime, 6.00 gal. at $1.90	=	11.40
Wall paint, 14.30 gal., say 14.5 gal. at $1.65	=	23.90
Turpentine 2 gal., and oil 1 gal. for thinning, say	=	2.50
Materials for sanding	=	2.20
Putty, at 1 lb. per 1,000 sq. ft., say 6 lb.	=	0.50
Total	=	$122.10

Labor, painters at \$1.10 per hour:		
Floors, 1,400 sq. ft., sand, fill, and varnish 3 coats		
$10.5 + 10.5 + 3 \times 8.4$	= 46.2 hr.	= \$ 50.80
Stairs, 132 sq. ft., sand, fill, and varnish 3 coats		
$2.0 + 1.0 + 3.0$	= 6.0 hr.	= 6.60
Trim (including stair rail) 450 lin. ft., sand twice, putty, stain, varnish 2 coats		
$11.70 + 6.0 + 6.30$	= 24.0 hr.	= 26.40
Doors and windows, 480 sq. ft., and twice, putty, stain, varnish 2 coats		
$12.5 + 6.0 + 7.2$	= 25.7 hr.	= 28.30
Trim, 642 ft., sand twice, putty, primer, flat paint 2 coats, enamel 2 coats		
$17.0 + 7.0 + 9.0 + 10.5$	= 43.5 hr.	= 47.85
Doors and windows, 565 sq. ft., sand twice, putty, primer, flat paint 2 coats, enamel 2 coats		
$14.5 + 7.0 + 8.0 + 9.0$	= 38.5 hr.	= 42.35
Walls, 2,380 sq. ft., size, paint 2 coats		
$1.5 + 33.5$	= 45.0 hr.	= 49.50
Total labor	= 228.9 hr.	= \$251.80
Equipment:		
General, \$18 plus sander \$5		= \$ 23.00
Overhead, 31 per cent of \$251.80		= 78.05
Profit, 10 per cent of \$474.95		= 47.50
Total estimate		= \$522.45

If desired, this estimate may be checked by using Diagram 15-1 for materials and Diagram 15-2 for labor.

Quantities are roughly as follows:

Floors and stairs, 1,532 sq. ft., sand, fill, varnish 3 coats.

Trim, stair rails, doors and windows, 930 sq. and lin. ft., sand twice, putty and stain, and varnish 2 coats.

Trim, doors and windows, 1,207 sq. and lin. ft., sand twice, putty and primer, 2 coats flat paint, 2 coats enamel.

Walls and ceilings, 2,380 sq. ft., size and paint 2 coats.

Materials, using Diagram 15-1:	
Filler paste at 0.35 gal. per square and \$0.80 per gal.	
Diagram gives \$0.28 per square 15.32 squares	= \$ 4.30
Floor varnish at 0.20 gal. per square and \$3.20 per gal.	
Diagram gives \$0.64 per square per coat, $\$0.64 \times 3 \times 15.32$ squares	= 29.40
Trim, stain, at 0.25 gal. per square and \$2.10 per gal.	
Diagram gives \$0.525, $\$0.525 \times 9.30$ squares	= 4.90
Trim, varnish at 0.20 gal. per square and \$3.20 per gal.	
Diagram gives \$0.64, $\$0.64 \times 2$ (coats) $\times 9.3$	= 11.90
Trim, prime and 2 coats flat at 0.20 gal. and \$1.85 per gal.	
Diagram gives \$0.37, $\$0.37 \times 3$ (coats) $\times 12.07$	= 13.45
Trim, 2 coats enamel at 0.25 gal. and \$2.80 per gal.	
Diagram gives \$0.70, $\$0.70 \times 2$ (coats) $\times 12.07$	= 16.90

Wall prime at 0.25 gal. per square and \$1.90 per gal. Diagram gives \$0.475. \$0.475 × 23.80 squares	= \$ 11.30
Wall flat paint at 0.30 gal. per square and \$1.65 per gal. Diagram gives \$0.495, \$0.495 × 2 coats × 23.80	= 23.60
Extra turpentine and oil	= 2.50
Putty	= 2.20
Sanding materials	= 0.50
Total materials	= \$120.95

Difference in estimates caused by taking quantities of paint to nearest quarter gallon in first estimate.

Labor, by using Diagram 15-2, wage \$1.10 per hour:

Floors and stairs, 15.32 squares	
Sand at 0.80 hr. per square. Diagram gives \$0.88, 15.32 sq.	= \$ 13.50
Fill at 0.75 hr. per square. Diagram gives \$0.825, 15.32 sq.	= 12.65
Varnish, 3 coats. Diagram gives at 0.625, \$0.69 per coat, 15.32 sq.	= 31.70
Total floors and stairs	= \$ 57.85
Trim, all stain and varnish, 9.30 squares equivalent	
Sand at 1.30 hr. per square. Diagram gives \$1.45. 2 sandings 9.30 sq.	= 27.00
Stain and putty at 1.30 hr. per square. Diagram gives \$1.45. 9.30 sq.	= 13.50
Varnish at 0.75 hr. per square. Diagram gives \$0.825. 2 coats. 9.30 sq.	= 15.35
Total trim stain and varnish	= \$ 55.85
Trim, paint, and enamel, 12.07 squares equivalent	
Sand at 1.30 hr. per sq. Diagram gives \$1.45. 2 sandings. 12.07 sq.	= \$ 35.00
Prime and putty at 1.20 hr. per square. Diagram gives \$1.32. 12.07 sq.	= 15.90
Flat paint at 0.70 hr. per square. Diagram gives \$0.77. 2 coats. 12.07 sq.	= 18.60
Enamel at 0.80 hr. per square. Diagram gives \$0.88. 2 coats. 12.07 sq.	= 21.25
Total trim, paint, and enamel	= \$ 90.75
Walls, prime and paint, 23.80 squares	
Prime at 0.50 hr. per square. Diagram gives \$0.55. 23.80 sq.	= \$ 13.10
Paint at 0.70 hr. per square. Diagram gives \$0.77. 2 coats. 23.80 sq.	= 36.70
Total for walls	= \$ 49.80
Total labor	= \$254.25
Equipment, general \$18, sander \$5	= 23.00
Overhead, 31 per cent of \$253.25	= 78.60
Profit, 10 per cent of \$475.80	= 47.70
Total estimate	= \$524.50

This painting estimate has been worked out in more detail, perhaps, than most estimators would consider necessary. Prices will vary in different localities at different times. Coverage by paint and rates of work will vary considerably also.

B. PAPERING

8. Papering.—The cost of papering will depend upon the cost of the wallpaper and paste, the cost of preparing the walls and ceilings, the area to be covered, the work required for papering including the work around openings and matching, and the wages, skill, and inclination of the workmen.

On new work, the plastered walls must be given a coat of sizing before the wallpaper is applied. The cost of sizing may be found as directed in the articles on Painting. The unit of measurement for sizing is usually the square of 100 sq. ft.

The materials and labor for papering are usually estimated per roll of paper instead of per square yard or per square of 100 sq. ft. The width of a roll of paper is usually 18 in., though some styles may have larger lengths. The length of a single roll is 24 ft., or 8 yd., and of a double roll 48 ft., or 16 yd. Borders are of varying widths and come in rolls. Borders may be estimated per linear yard or per roll.

9. Materials. *Sizing.*—If the plaster walls and ceilings must be given a coat of sizing, 1 gal. of glue sizing suitable for this purpose will cover 500 to 1,000 sq. ft. of surface and cost about $0.25 to $0.50 per gallon.

Wallpaper.—In the cheaper work where the strips may be pieced, the number of single rolls may be found by first obtaining the gross area of the walls and ceiling, deducting the area of the openings, and dividing the net area by 36 (sq. ft. in a roll) to obtain the number of single rolls. If the paper used on the ceiling is not the same as that on the walls, then walls and ceiling must be figured separately.

With the more expensive work where strips may not be lapped, the number of rolls required for the walls may be found by first finding the perimeter of the room in feet, and dividing this by 1.5 to obtain the number of strips. The number of strips that can be cut from one roll is found by dividing the length of the roll (single or double) by the length of a strip (height of room). The total number of strips divided by the number of strips that

can be cut from one roll will give the number of rolls required for the walls. The rolls required for the ceiling may be found in the same manner. Only half the area of openings of 20 sq. ft. or larger should be deducted to allow for cutting and fitting around openings.

For waste caused by matching, allow

5 per cent, for paper with no figured pattern.
10 per cent, for paper with a small figured pattern.
15 per cent, for paper with a large figured pattern.

Double rolls should be used as the waste caused by cutting and matching is less than with single rolls.

The length of border is found by measuring the perimeter of the ceiling in yards. The border is usually estimated in yards, but may be estimated in rolls.

Prices of wallpaper per double roll may vary from about $0.15 to $5 or more. Average costs are usually less than $1 a double roll. Border costs range from about $0.05 per yard and up.

Paste.—The amount of paste required will vary with the area and weight of the rolls. Paste may cost about $0.15 to $0.50 per gallon. One gallon of paste will be sufficient for about 3 double rolls of heavy-weight paper, 4 double rolls of medium-weight paper, and 5 or 6 double rolls of light-weight paper.

10. Labor.—If plastered walls and ceilings must be sized, the labor required for this purpose will vary from about 0.25 to 0.50 hr. per 100 sq. ft.

The time required to apply a roll of paper will depend upon the weight of the paper, length of roll, the pattern (matching required), the number of openings, and the skill and ability of the paper hanger.

TABLE 15-5.—APPROXIMATE LABOR REQUIRED FOR HANGING PAPER

Weight of paper	Double rolls per hour		Hours per double roll	
	Walls	Ceiling	Walls	Ceiling
Light	1.5–4.0	1.2–3.5	0.25–0.70	0.30–0.85
Medium	1.0–2.5	0.8–2.0	0.40–1.00	0.50–1.25
Heavy	0.7–2.0	0.5–1.5	0.50–1.40	0.65–2.00

Table 15-5 gives the approximate amount of labor required for double rolls (48 ft. or 16 yd. long). The labor required for applying border rolls will be the same as for other rolls of equal length.

Diagram 15-4 (page 640) may be used for finding the labor cost per roll for paper hanging when the hourly wage is known and the rate of work may be reasonably assumed.

11. Equipment.—The equipment required for papering will include stepladders and planks for scaffolding, cutting planks, paste buckets, brushes, shears, and other hand tools. The equipment costs for a small job may range from $5 to $15, including transportation. On large jobs, the equipment costs may be about $10 to $20 for each gang of about three to six paper hangers.

12. Overhead and Profit.—Overhead costs, based on labor, may range from 20 to 40 per cent, or from 15 to 25 per cent when based on the sum of material and labor costs. Profit may range from 8 to 15 per cent of the sum of all other costs.

13. Papering Estimates.—Papering estimates should include the costs of all materials, labor, equipment, overhead, and profit charged to the particular job. Estimates may show the cost per roll as well as total costs.

14. Illustrative Estimate.—Prepare an estimate for papering the living room of a residence.
Size of room is 12 × 20 by 8.5 ft. high.
Openings are

2 triple windows, 5 by 8 ft., each.
2 single windows, 3 by 5 ft., each.
1 double French door, 5 by 7 ft.

The room has an 8-in. oak baseboard at the floor and a combined oak cove and picture molding 4.5 in. wide around the ceiling.
The walls have not been painted or calcimined so that sizing will be needed.
Wall paper selected has medium-sized pattern and costs $0.85 per double roll. Ceiling paper costs $0.75 per double roll, and border costs $0.65 per roll of 16 yd.
Paper hanger's wage is $1.10 per hour.

Solution: Materials.

Walls. Perimeter = 64 ft. Strips = 64 ÷ 1.5 = 43.
Deduct for openings, $\frac{1}{2}(2 \times 5 + 2 \times 3 + 5) = 10.5$, or about 7 strips. Net 36 strips. Length of strip = 8.5 ft. less 1 ft. (trim) or about 7.5 ft. If pattern matches easily, 6 strips can be cut from 1 double roll 48 ft. long, otherwise only 5 strips. 38 strips ÷ 6 = $6\frac{1}{3}$ rolls, or may need 8. Assume 7.

Border = 64 ft. or $1\frac{1}{3}$ double rolls. Will need 2.

Ceiling. Strips crosswise. 20 ft. ÷ 1.5 = 14 strips needed.

Length of strip = 12 ft. less about 8 in., or 11.33 ft.

1 double roll would give 4 strips, if pattern matches readily, otherwise only 3 strips.

Rolls needed = 14 ÷ 4 = 3.5. Will need 4.

Materials cost.	Walls 7 × $0.85 =	$ 5.95
	Border 2 × $0.65 =	1.30
	Ceiling 4 × $0.75 =	3.00
	Paste, say 2 gal. =	0.60
	Sizing, say 2 gal. =	0.50
	Total	$11.35

Labor:

For sizing, about 64 × 8.5 + 12 × 20 − [2 × 5 × 8 + 2 × 3 × 5 + 5 × 7] or 544 + 240 − 145 = 639 sq. ft.

Assume 0.40 hr. per 100 sq. ft., time required will be

$$0.40 \times 639 \div 100 = 2.55 \text{ hr.}$$

Labor for papering walls at 0.70 hr. per roll gives 0.70 × 7 = 4.9 hr.

Ceiling at 0.80 per roll gives 0.80 × 4 = 3.2 hr.

Border at 0.70 per roll gives 0.70 × 2 = 1.4 hr.

Total labor = 12.05 hr., say 12 hr.

Labor cost = $1.10 × 12 = $13.20

Equipment costs will be low, say about $3 for transportation and depreciation.

Overhead, say one-third of labor costs, or $4.50.

Profit, say 10 per cent of all other costs, or about $3.

Summary:

Materials	$11.35
Labor	13.20
Equipment	3.00
Overhead	4.40
Profit	3.00
Total	$34.95

Or a cost of $34.95 ÷ 13, or $2.69 per roll.

C. GLAZING

15. Glazing.—The cost of glazing will depend upon the total area to be glazed, size of panes, quality of glass, price, difficulties of installing the glass in the frames, and the wages, skill, and inclination of the workmen.

For approximate estimates, the total area to be glazed with each quality or kind of glass is taken off and figures assumed for the costs of materials and labor per square of 100 sq. ft.

For more detailed estimates, the take-off shows the number and size of panes of each quality of glass, together with notes relating to the work on the particular job. Then the materials cost is computed. Labor output is assumed and labor costs computed.

Most sash used for windows and doors in ordinary building construction comes ready glazed. However, when steel sash is used in industrial buildings, the glass is usually installed after the sash is in place and there is little danger of breakage. If large steel sash were glazed before erection, they would be very difficult to handle, and the breakage would probably be large. Most steel sash is made so that the glass may be installed from the inside of the building. When glass must be installed from the outside, some form of swing scaffold may be used.

16. Materials.—For accurate estimates, the estimator should go over the plans and specifications and count the number of panes of each size and kind. Then the required glass should be listed as to size (dimensions) and kind. The kind may be single strength, double strength, plate, wire, ribbed, etc. The size is usually given in inches as 8 by 10, 10 by 16, 12 by 18, 14 by 20, etc. From 3 to 6 per cent should be allowed for breakage.

Window glass is usually packed in boxes containing approximately 50 sq. ft. Hence, two boxes are required for each square of 100 sq. ft. There are a great many sizes. Widths vary from 6 to 12 in. by 1-in. intervals, and from 12 up to about 30 in. by 2-in. intervals. Lengths vary from 8 to about 40 in. by 2-in. intervals, and above 40 in. by larger intervals. Manufacturers and dealers rarely stock all the various sizes. Hence, their catalogues and stock lists should be consulted for information regarding sizes and grades, and number of panes per box. Table 15-6 gives information about some of the various sizes, areas, and number of panes or pieces per box. To get the number of panes in a box, divide 50 by the area of one pane in square feet.

Single-strength glass may be used in the smaller sizes. Double strength should be used for panes larger than about 3 sq. ft. in area.

Prices of glass vary with the thickness (single strength, double strength), clearness or grade, kind (ordinary, plate, wire, etc.), and the areas of the panes. List prices are quoted to which

TABLE 15-6.—GLASS SIZES, AREAS, AND NUMBER OF PANES PER BOX OF 50 SQ. FT.

Size, in.	Net area of 100 panes, sq. ft.	Panes per box	Size, in.	Net area of 100 panes, sq. ft.	Panes per box
6 by 8	33.3	150	18 by 20	250	20
7 by 9	43.7	115	18 by 22	275	18
8 by 10	55.5	90	18 by 24	300	17
8 by 12	66.7	75	18 by 28	350	14
			18 by 34	425	12
10 by 12	83.3	60			
10 by 14	97.2	52	20 by 24	333	15
10 by 16	111.1	45	20 by 28	389	13
			20 by 34	472	11
12 by 16	133	38	20 by 40	555	9
12 by 20	167	30	20 by 46	638	8
12 by 24	200	25			
			22 by 28	358	12
14 by 16	155	32	22 by 34	519	10
14 by 20	194	26	22 by 40	611	8
14 by 24	233	22	22 by 46	703	7
14 by 28	272	19 (18)			
			24 by 28	467	11
16 by 20	222	23	24 by 34	567	9
16 by 22	244	21	24 by 40	667	8 (7)
16 by 24	267	19	24 by 46	767	7 (6)
16 by 28	311	16	24 by 52	867	6
16 by 34	378	13			
			26 by 34	613	8
			26 by 40	722	7
			26 by 46	831	6
			26 by 52	939	5

large discounts (say 75 per cent or more) apply. Approximate prices (1946) per box of 50 sq. ft. vary from about $2.75 per box and up for single-strength glass and from about $3.75 per box and up for double-strength glass.

About 1 lb. of putty is required for every 5 to 7 lin. ft. of stopping or puttying. Some estimators allow 1 lb. of putty for every 2 sq. ft. of glass, or about 25 lb. of putty per box of glass. For glazing steel sash, "steel-sash" putty should be used. This putty is provided at reasonable prices by the manufacturers of the sash. The price of putty may vary from about $0.05 to $0.10 per

pound. Table 15-7 gives the approximate amount of putty required for glazing.

TABLE 15-7.—POUNDS OF PUTTY REQUIRED PER 100 PANES AND PER BOX OF GLASS

Glass size, in.	Pounds putty		Glass size, in.	Pounds putty	
	Per 100 panes	Per box		Per 100 panes	Per box
8 by 12	56	42	16 by 22	115	24
10 by 16	75	34	16 by 34	155	20
12 by 20	93	28	20 by 28	150	19.5
14 by 20	100	26	20 by 40	185	16.5
14 by 28	125	24	24 by 38	160	17.5
			24 by 46	215	15

Diagram 15-5 (page 641) may be used for estimating costs of glass when the price per box is known. Curves are shown for glass with breakage allowances of 0.5 and 10 per cent and for glass plus breakage allowances plus an allowance of $1.25 per box for putty.

17. Labor.—Labor costs vary greatly because of the difficulties found on the particular job, the weather, and the skill and inclination of the workers. A good average rate of work is about 100 panes, 14 by 20 in. in size, per 8-hr. working day. Some jobs may run as low as 50 a day, and other jobs may run as high as 200 per day. More time is usually required (about 10 per cent) to glaze monitors and roofs than to glaze side walls. Compared with summer work, winter work may require up to 20 per cent more time, depending upon the severity of the weather. The larger the size of the light, the more the time required per light for glazing.

TABLE 15-8.—LABOR REQUIRED FOR GLAZING STEEL SASH

Glass size, in.	Panes, per hour	Labor-hours per 100 panes	Glass size, in.	Panes per hour	Labor-hours per 100 panes
10 by 16	12–17	6– 8	16 by 22	9–12	8–11
12 by 18	11–17	6– 9	24 by 34	4– 6	18–27
14 by 20	10–14	7–10	34 by 46	3– 5	22–30

Table 15-8 gives the approximate number of hours required by skilled workers for glazing 100 lights or panes. Summer weather and side walls are assumed.

Glazing may also be estimated per square of 100 sq. ft. Average rates of work are about as follows:

TABLE 15-9.—LABOR-HOURS PER SQUARE OF 100 SQ. FT. OF GLAZED SURFACE

Size of panes	Square feet per labor-hour	Labor-hours per square
Small, 1.5 sq. ft. or less...........	14–15	4.0–7.0
Medium, 1.5 to 4.0 sq. ft..........	18–33	3.0–5.5
Large, 4.0 sq. ft. or more..........	22–40	2.5–4.5

Glazing is often done by painters, and prevailing hourly wages apply. In some places, glazing is done by a special crew of glaziers who receive comparatively high pay and who have a high hourly output. Sometimes the glazing is paid for on a piecework basis with varying rates for panes of different sizes. Wages of skilled workmen may vary from about $1 to $2 per hour.

Diagrams 15-6 and 15-7 (pages 642 and 643) may be used for estimating the cost of glazing.

Steel sash are usually erected by structural-steel or iron workers and not by the glazier. The painting or calking of the steel sash may be done by steelworkers, masons, or handy men and rarely by painters or glaziers.

18. Equipment.—The cost of equipment for a glazing job is usually small. The equipment needed may consist of a swinging scaffold, ladders, stepladders, putty knives, and glass cutters. Transportation will be needed for scaffolds and ladders. The glaziers can move the swinging scaffold and ladders as needed. An allowance of about $10 to $20 is usually sufficient for a small gang of about three to five men.

If built-up scaffolds are required, these should be estimated separately. The estimate should include all materials and all labor needed for erection, moving, and dismantling.

19. Overhead and Profit.—Overhead is usually based on labor costs and may range from 20 to 45 per cent. When based on the sum of materials and labor, the percentage may range from 10 to 25 per cent.

The percentage allowed for profit may vary from 8 to 20 per cent of the sum of all other costs.

20. Glazing Estimates.—Glazing estimates should include the costs of all materials delivered at the job (including freight, insurance, truckage, handling, storage, and breakage), and the costs of labor, equipment, overhead, and profit.

If desired, estimates may be subdivided to show costs per sash, costs per light or pane (of each size), or costs per 100 sq. ft. of glass.

21. Illustrative Estimate.—Estimate the costs of materials, labor, equipment, overhead, and profit for the following job of glazing steel sash. All lights are double strength (DS) AA grade clear glass.

Size of lights, inches	No. of lights	Square feet
10 by 16	250	278
12 by 18	300	450
14 by 20	672	1307
20 by 22	154	471

Cost of lights is $5.65 per box of 50 sq. ft. delivered at the job.
Cost of sash putty is $0.06 per pound.
Labor wage is $1.20 per hour.
Equipment costs assumed as $17 for the job.
Overhead assumed as 26 per cent of labor cost.
Profit assumed as 12 per cent of all other costs.
Materials (Allow 3 to 5 per cent for breakage):

250 lights, 10 by 16 in., 45 per box, say	5.75 boxes		= $ 32.50
300 lights, 12 by 18 in., 34 per box, say	9 boxes		= 51.00
672 lights, 14 by 20 in., 26 per box, say	27 boxes		= 152.50
154 lights, 20 by 22 in., 16 per box, say	10 boxes		= 56.50
Total lights	51.75 boxes		= $292.50
Putty 75 × 2.50 =	190 lb.		
90 × 3.00 =	270 lb.		
100 × 6.72 =	672 lb.		
125 × 1.54 =	193 lb.		
Total	= 1,325 lb. at $0.06		= $ 80.00
Materials total			= $372.50

Materials costs for glass may be checked by the area method.
Total area = 2,506 sq. ft. plus 4 per cent for breakage gives
2,600 sq. ft., or 52 boxes at $5.65 = $294
Putty at 26 lb. per box = 1,350 lb. at $0.06 = 81
Total materials = $375

CHAPTER XVI

HEAVY MACHINERY

1. Estimating Machinery.—The estimation of the costs of heavy machinery is a special problem in the handling, transporting, and installing of comparatively large and heavy objects. Nearly every problem of this kind includes such items as the following:

Machinery cost, usually f.o.b. factory. Sometimes the manufacturer allows or prepays freight to destination.

Freight to most convenient railway siding, if shipped by railroad, including demurrage and other extra charges.

Freight to site if shipped by truck.

Transporting, erecting, operating, and taking down of special equipment required for handling heavy machinery.

Unloading from railway car and transporting from railway car to site, or unloading from truck at site.

Installing the machinery in place, which may include erection, setting, lining up, and grouting.

Miscellaneous work which may include the construction of foundations, and the removal and replacing of building walls and roofs.

On some jobs, the owner or general contractor assumes the cost of the machinery f.o.b. destination and a subcontractor cares for the handling, transportation from railway siding to site, and installation at the site. When preparing estimates for the subcontractor, the materials cost (except that for miscellaneous materials) is omitted. Insurance is cared for in the overhead costs.

When preparing an estimate for heavy machinery, the estimator must have information concerning the kinds, sizes, and weights of the machinery; the method of transportation from factory to destination; the kinds of equipment the contractor may have or may be able to secure by rental or purchase; the ability and skill of the foreman and crew; the methods that may be satisfactorily and economically used for handling, trans-

On many jobs, miscellaneous materials may be required, such as bolts and washers, materials for making grout, or masonry materials as the case may be. The costs of these miscellaneous materials delivered at the job should be estimated and preferably included in the materials cost.

3. Labor.—The labor required may include the following:

Handling. Unloading from railway car to ground or to truck, trailer, or dollies, and unloading at the site. The machinery may be unloaded from the railway by means of a crane, derrick, or gin pole; by means of jacking, bulling, or skidding on small rollers as the case may be.

Transportation. Extra labor is often required to help in the transportation of the machinery to the site. The machinery may be moved on skids and small rollers, on heavy four-wheel trucks or dollies, on large-capacity autotrailers, or on large-capacity trucks. The extra labor required will vary with the particular job.

Installation. The labor required will depend on the kind, size, and weight of the machines, the equipment provided, and the methods used. This labor may include the labor cf erection as for a steel smokestack, the labor of setting or placing a machine (such as an engine or dynamo) in position, lining up and plumbing the machine after setting, fastening the machine in position by bolting, riveting, or grouting.

Equipment. Labor will always be required for moving, erecting, operating, taking down, loading, and unloading equipment of various kinds.

Miscellaneous. On many jobs, labor may have to be provided for constructing foundations, setting anchors and anchor bolts, removing and replacing walls and roofs, etc.

The size of the gang will vary with the machine to be installed, the equipment used, and the kind of work. Usually, a gang will contain about 4 to 10 men under a capable foreman. The gang may be composed of foreman, skilled labor (truck driver, crane operators, steelworkers, masons, etc.), and unskilled labor, depending on the kind of work. When conditions permit it, as many unskilled men should be used as practical. If the men in the gang are used to working together under the particular foreman, there may be a considerable saving in labor time on work of this kind, when compared with a green or inexperi-

enced gang. There is a skill or knack of handling heavy machinery that can be acquired only by experience.

The wages of the men may vary about as follows:

Foreman	\$1.50 to \$4.00 per hour
Skilled labor	\$1.00 to \$3.00 per hour
Unskilled labor	\$0.50 to \$1.50 per hour

The labor of handling, transporting, and installing heavy machinery can be most conveniently estimated in labor-hours per ton, with details noted in regard to machinery, equipment, and working conditions. Sometimes a heavy machine can be handled at less cost per ton than a light machine.

The labor required for the equipment may be estimated in labor-hours required for each kind of equipment.

The labor required for miscellaneous work may be estimated in labor-hours for the particular job according to the kind and quantity of work to be done.

Tables 16-1 to 16-4 give the labor-hours per ton required for doing various kinds of work. The values given are necessarily very approximate, and must be so considered. It is practically

TABLE 16-1.—APPROXIMATE LABOR-HOURS FOR HEAVY MACHINERY

Item	Labor-hours	
Bulling and moving or turning up to 8 or 10 ft.	1 – 2	per ton
Jacking up or down, and placing or removing cribbing	0.5 – 1.0	per ton per foot of height
Jacking up and installing skids	1 – 2	per ton
Moving on skids and small rollers	0.5 – 1.5	per ton per 100 ft.
Unloading, from car to ground, from car to truck or trailer, from truck or trailer to ground, with use of derrick or gin pole	1 – 6	per ton
Erecting with use of derrick or gin pole (steel stack for example)	2 – 12	per ton
Setting, plumbing, etc. (steam boiler, for example)	1 – 3	per ton
Lining up, roughly	0.5 – 3	per ton
Lining up, accurately	3 – 15	per ton
Grouting	0.10 – 0.25	per ton
Installing guy wires on stack	1 – 3	per guy wire
Riveting, hand-driven field rivets	12 – 25	per 100 rivets
Jacking up or down, and placing or removing large dolly trucks	1 – 5	per ton

impossible to give accurate information because of the differences in working conditions, variations in the skill and ability of the foreman and men, variation in equipment, and differences in kinds of machinery.

TABLE 16-2.—APPROXIMATE LABOR-HOURS REQUIRED FOR UNLOADING, ERECTING, AND LINING UP CERTAIN KINDS OF MACHINERY

Kind of machinery	Work	Labor-hours per ton
A. Large and bulky machinery such as smokestacks, shells, and tanks weighing about 1 to 5 tons per piece. (Smokestack and like types requiring riveting and guying.)	Unload car to truck or trailer or to ground	2 – 8
	Unload truck or trailer to ground	1.5– 6
	Erect only	3 –10
	Erect and rivet sections	6 –20
	Erect and line up	5 –15
	Erect on ground, hand rivet, guy	8 –25
	Erect on roof, hand rivet, guy	10 –35
B. Heavy but not bulky machinery such as boilers, compressors, engines, and motors weighing 2 to 10 tons per piece.	Unload car to truck or trailer or to ground	2 – 7
	Unload truck or trailer to ground	1 – 5
	Set and roughly line up	2 – 6
	Accurately line up when required	3 –18
C. Heavy but not bulky machinery such as engines, boilers, and motors weighing 10 to 50 tons per piece.	Unload car to trailer or to ground	2 – 6
	Unload trailer to ground	1 – 5
	Set and roughly line up	2 – 5
	Accurately line up when required	3 –15

The values given do not include any labor for equipment such as labor of unloading, erecting, rigging, taking down, and loading derricks or gin poles, but do include labor of arranging ordinary cribbing and blocking.

Labor Diagrams.—Diagram 16-1 (page 644) may be used for estimating the labor cost of handling and installing heavy machinery, and Diagram 16-2 (page 645) for estimating the labor cost for equipment.

4. Equipment.—The equipment used for handling, transporting, and installing heavy machinery will depend upon the needs

TABLE 16-3.—APPROXIMATE LABOR-HOURS REQUIRED FOR EQUIPMENT

Item	Labor-hours
Handling cribbing and timbers, per 100 pieces	1– 5
Gin pole or guy derrick, large, 15- to 30-ton capacity:	
Unload and erect	40–100
Take down and load	15– 50
Gin pole or guy derrick, small, 5- to 15-ton capacity:	
Unload and erect	20– 50
Take down and load	8– 20
Stiffleg derrick, large, 25- to 60-ton capacity:	
Unload and erect	150–300
Take down and load	80–150.
Stiffleg derrick, medium or small, 10- to 30-ton capacity:	
Unload and erect	60–150
Take down and load	30– 80
Hand derrick, small, 1- to 5-ton capacity:	
Unload and erect	15– 40
Take down and load	8– 20

TABLE 16-4.—APPROXIMATE EXTRA LABOR REQUIRED WITH EQUIPMENT

Item	Extra Labor
With each autotruck	1 driver, 1 or 2 helpers
With each autotruck trailer	1 to 3 helpers
With each set (3 or 4) of heavy dolly trucks	2 to 4 helpers
With each hand windlass	2 to 5 helpers
With each crane or derrick (power)	1 foreman, 1 operator, and 4 to 10 helpers
For handling cribbing or timbers	2 or more
For jacking, bulling, cribbing, etc. (About 2 plus 1 to 3 for each 10 tons of weight)	1 foreman, and 2 to 12 helpers

of the particular job, the methods that may be used, the equipment available (either owned or rentable), and what the contractor thinks should be used. There are, consequently, a great variety of combinations of kinds and sizes or capacities of equipment that may be considered. In this text, some of the equipment that may be used will be listed. The reader is referred to texts on construction methods for the proper selection of equipment and its use.

To find the equipment costs for a given job, all equipment used must be listed with the costs, and the total found. The cost per ton equals the total equipment cost divided by the tonnage of the machinery.

TABLE 16-5.—VARIOUS TYPES OF EQUIPMENT THAT MAY BE USED FOR HANDLING, TRANSPORTING, AND INSTALLING HEAVY MACHINERY

Handling, loading, and unloading:	Erection or installation:
Cribbing and timbers	Cribbing and timbers
Skids and small rollers	Jacks
Jacks	Gin poles
Pinch, claw, and crow bars	Shear legs and A frames
Dollies, small	Cranes and derricks, both hand and power
Gin poles	Crawler cranes
Shear legs and A frames	Block and tackle
Stationary cranes and derricks	Wire and manila rope
Crawler cranes	Various small and hand tools
Hand and power operated cranes and derricks	Ladders
Winches	Scaffolds
Block and tackle	Slings
Wire and manila rope	Welding equipment
Small tools	Riveting equipment
Transporting:	Air compressors
Autotrucks	Steelworkers' tools
Autotrucks and trailers	Grouting equipment
Heavy four-wheel dollies	Mason's tools
Skids and rollers	Roofers' equipment
Winches	
Block and tackle	
Wire and manila rope	
Various small and hand tools	
Lighters	
Tugs	
Floating cranes and derricks	

Rental costs may be per hour, per day, per week, or per month with certain minimum charges. The daily rate may be based on a day of 10 hr. or less. The hourly rate may be $\frac{1}{10}$ or $\frac{1}{8}$ of the daily rate. The weekly rate may be three to four times the daily rate. The monthly rate may be about three times the weekly rate. Rental rates start at the time the equipment is turned over to the renter, either at the job site or f.o.b. the nearest railway siding. Rental rates may include machine and fuel, major but not minor repairs, and may or may not include an operator. They usually do not include transportation and freight.

The best method of estimating equipment costs is to first estimate the number of days that each piece of equipment will be used or held available for use. Then the total cost of one

piece of equipment for the job would include daily ownership or rental cost times number of days held or used on the job, plus transportation costs to and from the job, plus maintenance, and plus labor costs of operation, erection, takedown, etc. (if these labor costs are not included in the labor estimate).

Information concerning ownership and rental costs of various pieces of equipment is given in Appendices B and C.

The equipment costs per ton of heavy machinery is a suitable unit to use for approximate estimates when, and only when, the estimator has adequate information. Naturally the costs per ton of machinery will vary considerably with the different kinds of equipment used, the sizes and weights of the machinery, the skill of the foreman and crew, and the transportation costs of the equipment to and from the job. The labor costs of erecting, operating, moving, taking down, loading, and unloading equipment are usually included in the labor estimate.

Table 16-6 gives approximate equipment costs per ton of heavy machinery for different kinds of equipment. The values

TABLE 16-6.—APPROXIMATE EQUIPMENT COSTS PER TON OF HEAVY MACHINERY

Transportation and labor costs are not included

Item	Cost per Ton
Handling, loading, and unloading:	
Cribbing and timbers	\$0.10–\$1.50
Skids and small rollers or dollies	0.20– 2.00
Jacks	0.05– 0.25
Hand tools, hammers, bars, etc	0.10– 1.00
Small gin poles, shear legs, A frames, etc	0.10– 3.00
Hand derricks and cranes	0.10– 3.00
Medium and large stationary cranes and derricks	0.20– 4.00
Block and tackle, and wire and manila rope	0.10– 1.00
Crawler cranes	0.20– 4.00
Transportation:	
Autotrucks (\$1 for load and unload + 0.10 per ton mile)	1.10– 4.00
Autotrucks and trailers (ton costs about same as for autotrucks)	1.25– 5.00
Heavy four-wheel dollies (set of 3 or 4), per mile	0.20– 0.50
Skids and rollers or small dollies	0.25– 1.00
Winches	0.20– 1.50
Block and tackle and wire and manila rope	0.10– 1.00
Erection:	
See items under Handling, loading, and unloading	
Ladders, slings	0.10– 0.50
Scaffolds	0.10– 2.50

given do not include transportation costs of equipment to and from the job and labor costs of loading and unloading, erecting, moving, operating, and taking down the equipment, unless otherwise specified.

The range in costs as given in Table 16-6 is quite large for several reasons. For example, one piece of equipment with a minimum rental price of $5 per day may be required for handling a machine of 2 tons weight, giving a cost of $2.50 per ton. On another job, a similar piece of equipment may be used to handle several machines in a day with a total tonnage of, say, 50 tons. This would give a cost of but $0.10 per ton. An example would be a crane or derrick unloading machinery at a railway siding.

The cost of transporting heavy machinery with autotrucks or with autotrucks and trailers may be determined approximately by the formula

$$\begin{pmatrix}\text{Cost per ton}\\ \text{of machinery}\end{pmatrix} = \begin{pmatrix}\text{cost of loading and}\\ \text{unloading per ton}\end{pmatrix} + \begin{pmatrix}\text{cost per}\\ \text{ton mile}\end{pmatrix} \times \begin{pmatrix}\text{miles hauled}\\ \text{loaded}\end{pmatrix}$$

Loading and unloading costs may range from $0.75 to $2.00 per ton, and the cost per ton-mile may range from about $0.07 to $0.20.

Diagrams.—Diagram 16-3 (page 646) may be used for estimating equipment costs, and Diagram 16-4 (page 647) for estimating transportation costs.

5. Overhead and Profit.—Overhead costs may be comparatively large, because of the job hazards and the fairly high rates for compensation insurance and for other special insurance that may be charged. The overhead costs may be based on the sum of material, labor, and equipment costs, based on labor costs alone, or based on material, labor, and equipment costs using different rates or percentages for each.

When based on labor costs alone, overhead costs may range from about 40 to 70 per cent of the labor costs.

When different rates are used for materials, labor, and equipment, approximate variations are

From 2 to 10 per cent of the materials cost.

From 30 to 60 per cent of the labor cost.

From 3 to 10 per cent of the equipment cost.

The profit charged on a heavy machinery job is usually fairly high. Average rates may vary from about 8 to 25 per cent of the sum of all other costs.

6. Heavy-machinery Estimates.—The estimate for heavy machinery should include:

Materials. Cost of machinery, freight, and miscellaneous materials.

Labor. All labor costs of handling, transporting, and installing the machinery.

Equipment. All equipment costs.

Overhead. Usually based on labor costs.

Profit. Based on sum of all other costs.

The estimate may be in more detail if desired, and unit costs per ton of machinery may be computed.

Some estimators arrange their estimate differently by separating the handling and transportation and installation costs about as follows:

Materials. Cost of machinery, freight, and miscellaneous materials.

Handling and transportation. From railway car to job site.
- Labor. Cost of all labor used for this purpose.
- Equipment. Cost of all handling and transporting equipment.

Installation, erecting, setting, lining up, grouting, etc.
- Labor. Cost of all labor of installation.
- Equipment. Cost of all equipment used for installation.

Overhead. As a separate item, or subdivided under materials, handling and transportation, and installation.

Profit. On sum of all other costs.

7. Illustrative Estimates. *Steam Boiler.*—Prepare an estimate of the cost of unloading from a railway car a return tubular steam boiler weighing 12 tons, transporting the boiler 3 miles to the job site, and erecting the boiler on its foundations. As the walls and roof of the boiler house have not been built, it will not be necessary to make an opening in the walls. Boiler is mounted on skids and was shipped on a flatcar.

Boiler is to be unloaded from flatcar to trailer, transported 3 miles to job site, unloaded, and placed in position. The following data are assumed:

Rental of suitable truck and trailer, 1 driver and 1 helper, included..................	$60	per day
Miscellaneous cribbing, timbers, small rollers, tools, etc., including transportation......	$12	per job
Workmen..............................	$ 1.00	per hour
Foreman..............................	$ 2.00	per hour

Overhead, 38 per cent of labor cost (excluding truck driver and helper).

Profit, 12 per cent of all other costs.

First day.

Unloading, car to trailer.

Place rollers under skids, place timber and cribbing, load on trailer, place cribbing, etc., on truck.

Use a gang of 1 foreman and 5 laborers.

Hourly wage of the gang = $2 + $1 × 5 = $7.00

Average hourly wage, foreman supervising only

$$= \frac{\$2 + \$1 \times 5}{5} = \$1.40$$

Estimate about 2.5 hr. per ton, or 2.5 × 12 = 30 labor-hours, or about 6 gang-hours.

Trucking 3 miles to job site may require about 1 hr.

Unloading, trailer to timbers on ground, about 1.25 hr. per ton, or 1.25 × 12 = 15 labor-hours, or about 3 gang-hours.

This will take a day of 10 hr.

Second day.

Skid and roll boiler to foundation, lower and set on foundation, hang doors, clean up and remove all equipment. This is estimated to take about 2.25 hr. per ton, or 2.25 × 12 = 27 labor-hours. Or about 5.5 gang-hours.

Total gang-hours for both days = 15.5

Summary (no materials cost):

Item	Cost per Ton	Total Cost
Labor, $7 × 15.50	$ 9.04	$108.50
Equipment, $60 + $12	6.00	72.00
Overhead, 38 per cent of $108.50	3.44	41.30
Profit, 12 per cent of $221.80	2.22	26.60
Total	$20.70	$248.40

NOTE: In regard to this particular estimate, a like job was done in the year 1936 at a net cost of $116. The contractor used his own truck and trailer, hired labor for $0.40 per hour, allowed $10 for overhead, and allowed $15 for his wages and profit. In 1938, six similar jobs in five different states cost $136, $149, $152, $192, $198, and $222.

Smokestack.—Prepare an estimate of the cost of unloading from a railway car to trailer a steel smokestack 3 ft. in diameter and 50 ft. high, transporting the smokestack 3 miles to the job site, riveting the sections together (the stack comes in three sections), and erecting the stack on the roof of the boiler house. Weight of stack is about 3 tons. The stack is to be erected by using a suitable gin pole. The contractor has the requisite equipment.

The following data are assumed:

Gin pole and rigging. owner's cost per day..........	$ 2.00
Truck, 5 ton, with power winch mounted back of seat, daily cost....................................	15.00
Two-wheel trailer, 5 ton, suitable for moving stack sections, gin pole, other equipment, daily cost.....	1.00
Equipment for cold riveting and rivets, job cost, estimated....................................	12.00
Miscellaneous tools and equipment, job cost estimated	5.00
Contractor acts as foreman, hourly wage............	2.00
Five workmen, one acting as truck driver, hourly wage	1.00
Overhead, 38 per cent of labor cost.	
Profit, 12 per cent of all other costs.	

Stack sections may be unloaded from flatcar to trailer, and from trailer to ground, by hand labor without use of gin pole. Gin pole is used for erection only.

Stack labor:

Unloading stack from car to trailer, say 4 labor-hours per ton or section, giving..............................	12 labor-hours
Unloading at job site, a little less, say.................	10 labor-hours
Cold-riveting sections together, about 90 rivets at 20 hr. per 100 rivets, say.............................	18 labor-hours
Erecting stack, including raising to a vertical position, raising to roof of boiler house, and setting with aid of gin pole and wench on truck, say about 9 labor-hours per ton or..................................	27 labor-hours
Guying 4 guys, say..................................	4 labor-hours
Trucking, assume 1 hr. with gang....................	5 labor-hours
Total for stack..................................	76 labor-hours

Equipment labor:

Loading gin pole and other equipment at contractor's yard..	4 labor-hours
Unloading at job..................................	3 labor-hours
Erecting and rigging gin pole........................	20 labor-hours
Takedown and load, gin pole........................	8 labor-hours
Unload again at contractor's yard	3 labor-hours
Trucking 2 hr. with gang............................	10 labor-hours
Total for equipment................................	48 labor-hours
Total for job..	124 labor-hours
Gang-hours for a gang of 5 men......................	25 gang-hours

Selection and arrangement of equipment suitable for the job, consideration being given to kind of work, amount of work, characteristics of site, equipment available, etc.

No piece of equipment should be used on any job unless this use will be economical, especially in regard to costs.

Whenever the topography of the site permits, gravity should be utilized for handling materials.

Capacities of machines should be sufficient for the work, so that neither overloading or idling is required. That is, for efficient operation, machines should be worked as near their rated capacities as possible.

Machines should be located so that they may be used efficiently and also so that the number of moves will be a reasonable minimum.

The tendency toward accidents and delays should be reduced whenever possible. A stock of spare parts kept on the job will tend to reduce the time of delays caused by breakdowns in machinery.

Remember that the sum of all items of unit cost must be a minimum.

3. Construction Plant Required for a Job.—The methods followed in various construction jobs are partly standardized according to the kind of work, amount of work, and location. Construction equipment is also standardized to some extent, different machines being developed for different kinds of work. Consequently, the contractor and his estimator should have a good knowledge of suitable methods and equipment for any particular job.

The following will give a general idea in regard to the different equipment required for various jobs:

Earth excavation may need power shovels, cranes, derricks, grab buckets, plows, picks, shovels, scrapers, etc.

Rock excavation may need explosives, drills, and other tools.

Materials transportation may require motor trucks, trailers, tractors, wheelbarrows, wagons, belt conveyors, and unloading and loading equipment.

Piling may require pile drivers, hammers, templates, caps, points, etc.

A concrete building may require wood-working machinery for forms, bar benders, and cutters, bins for storing aggregates,

cement sheds, proportioning equipment, mixers, towers, and hoists, barrows, chutes, belts. pumps, etc.

A structural-steel office building may require guy or stiffleg derricks, riveting equipment, etc.

An industrial type steel building may need a gin pole or tractor crane, riveting equipment, etc.

A concrete highway may need excavating machinery, road-working machinery, autotrucks, tractors, concrete pavers, etc.

The equipment required for various kinds of work has been discussed in most of the preceding chapters. For further information, the reader is referred to such texts as "Handbook of Building Construction" by Hool and Johnson, "Construction Planning and Plant" by Ackerman and Locher, and "Standard Construction Methods" by Underwood.

4. Plant Design.—Construction-plant design includes the selection and arrangement of the construction plant or equipment needed for any particular construction job.

Before selecting the construction plant and planning the arrangement or layout, the site should be visited and conditions studied. Notes should be taken in regard to the location of the work, kind of soil, availability of power, light, water, and sewer, local ordinances and regulations, highways and other transportation facilities, railway yards, material dealers, banking facilities, local labor supply and conditions, boarding and rooming places for workmen, etc. Sketches are often helpful and should be made. In some instances, topographic maps are needed.

Having the various details concerning the site in mind, and knowing the kind and amount of construction work to be done, the contractor or his estimator must be able to visualize the work to be done, starting with the preliminary operations and following through to the final operations. Then the various pieces of equipment may be selected and the arrangement or layout prepared.

The equipment selected for any particular job will depend on what is thought to be desirable, what the contractor has available, and what he may reasonably expect to acquire by purchase or rental. Each piece of equipment must be suitable for the work to be done. The type and capacity of each machine must be such that it may be operated economically in connection with the other machines and the workmen on the job. That is, all pieces of equipment should be of such size and capacity that the

plant is "balanced." By a balanced plant is meant one in which each machine will be operating efficiently and at practically full capacity without any idleness or delays.

Sometimes the contractor has all the desired equipment, and at other times he must purchase or rent additional equipment. Whether the contractor should purchase new or secondhand equipment, or rent it, may depend upon his finances and the particular job. If the job is a comparatively small one, or if a certain kind of equipment is needed that may be rarely used afterward, the contractor may find it advisable to rent the equipment. However, if the needed equipment is such that the contractor may find use for it on other jobs, he may find it advisable to purchase the equipment either new or secondhand. Sometimes good standard secondhand equipment may be purchased at reasonable prices.

After the equipment has been selected, a layout should be prepared showing the arrangement of the equipment. The layout may be a map or sketch showing the location of each major piece of equipment and all the probable moves. Notes may be made explaining the reasons for the locations of the machines on the map and their probable moves. If possible, all the construction plant should be located at the site as it is then easier to superintend the work of this equipment. However, on some jobs, some equipment may be needed at the railroad siding, other equipment at the contractor's shop, or yard, and the remaining equipment at the job site. Conditions vary on different jobs, and the equipment must be arranged to the best advantage for the job in question. The equipment should be arranged so that the work will progress from one machine to another without unnecessary travel or delays.

When selecting the equipment and planning the layout, consideration should be given to the following:

1. Plant should be "balanced." Capacities of machines should be such that neither overloading nor idling of machines is necessary.

2. Power supply should be sufficient at all times. A small excess of power is advisable.

3. Power supply should be arranged so that a breakdown of one machine will not cause others to be shut down.

4. A reasonable stock of spare parts should be kept on hand so as to reduce the time lost by minor breakdowns.

5. Supplies of fuel, water, lubricants, and accessories should be sufficient at all times.

6. Stock piles should be placed as close to place of final use as practicable. The material having the greatest bulk should be placed the closest.

7. If power equipment is used for handling materials, handling by man power should be kept at a minimum.

8. Each tower, derrick, hoist, etc., should be located so that it will serve as large an area as practicable and also so that the moves will be a minimum.

9. Mixers, saws, batchers, etc., should be placed so that their output may be delivered as closely to the work as is possible.

10. Gravity should be utilized for handling materials and parts of the work whenever practicable.

11. Sufficient small tools of various kinds should be provided.

12. The plant layout should be such that the total amount of work, as measured in foot-pounds of work or energy, should be a minimum.

5. Plant Design for a Reinforced Concrete Building.—The following discussion will give an idea as to how the concrete-plant problem for a proposed reinforced concrete building may be considered.

Before the plant design for a reinforced concrete building is started, the site should be visited and the location of the building noted, together with the space available for the construction plant. The topography of the ground has some effect on the plant layout, in that the materials preferably should not be moved up hill, and that the force of gravity may be used to assist in the moving of the materials if the site is sloping. Such things as location of railway sidings, paved or unpaved streets leading to the site, availability of water and power, and sometimes the available labor supply have an effect on the plant design.

It is advisable to make a map of the site and show the location of the proposed building, field office, form-lumber piles, form work-benches, steel piles, steel-fabricating benches, aggregate storage, cement storage, mixer, towers, hoists, derricks, and other construction items in detail. In instances where the available space

The method used in getting the materials to the mixer is important. If the storage space is ample, comparatively large piles of coarse and fine aggregates may be placed near the mixer (the coarse aggregate should be closer, as it is larger). The cement should be stored in a weather-tight shed. If the storage space is small, it may be necessary to have the materials stored elsewhere and hauled to the mixer by trucks. Care must be taken to keep dirt and other impurities out of the aggregates. If necessary, the mixing plant should be placed elsewhere, and the mixed concrete hauled to the work in trucks.

Efficient operation of the mixer is necessary for economical work. The time required for loading will vary from 10 sec. to 1 min., with an average of about 20 sec. The time of mixing should never be less than 1 min., though many mixer operators try to gain time by reducing the time of mixing. The time required for unloading requires from 10 sec. to 1 min., with an average of 30 to 35 sec. Thus the total time required for a mixing cycle varies from about 1½ to 3 min., with an average of about 2 min. Of course, it is improbable that a batch every 2 min. could be produced hour by hour and day by day, because of delays in getting the materials to the mixer, delays in placing the mixed concrete, and delays due to breakdowns of some part of the plant.

The apparatus for measuring the materials (cement, fine and coarse aggregates, and water) for the batch must be such that the materials can be accurately and quickly measured and the correct proportions of the mix provided in all cases.

The concrete coming from the mixer may be transported to the forms in one of several ways. No matter which transportation method is chosen, the conveyance used should have a capacity equal to, or a little greater than, that of the mixer, so that the operation of the mixer will not be slowed up. The method selected may be one of the following:

1. By barrows or carts, in which the concrete is wheeled from the mixer to the forms. A tower and a hoist may be used for raising the carts and barrows to higher levels.

2. By a tower and spouting system, where the concrete is discharged into a skip or bucket, and this skip hoisted up a tower and dumped into a hopper, from which the concrete flows through spouts to its place in the forms.

data for computing plant costs. When a contractor rents equipment, he may estimate the costs by adding to the rental all other expense items that may be involved. Some contractors that own their equipment assume that they are renting the equipment from themselves and then figure the costs accordingly. At the present time, the use of the methods and data published by the Associated General Contractors is increasing. A brief discussion of this method is given in Appendix B. The reader is referred to the latest publications of the Associated General Contractors for complete detailed information.

Ownership Costs.—When a contractor owns his own equipment, the cost items include first cost, freight, insurance, overhead, interest on investment, depreciation, major repairs, salvage value, storage, transportation to and from jobs, installation (erection and removal), moves, operation, and minor repairs.

The first cost of a plant includes many things besides the factory price, f.o.b. cars. Some of these things are freight or express, bonus for prompt delivery, cost of tracing, and unloading. The cheapest plant may not always be the most economical when other cost items are considered.

The cost of installation varies with the type of plant, location of the job, cost of labor, moving charges, erection cost, and other details.

The cost of operation depends upon such things as the machines, the plant arrangement, the organization, the character and ability of men in charge of the plant, and the weather. The cost includes such items as wages of operators, cost of oil, and power (electric, steam, or gasoline).

The maintenance cost includes such items as the upkeep of the machines and the repairs, and also depends somewhat upon the mechanical excellence of the plant and the care with which the plant is operated.

The cost of removal includes the labor cost of dismantling the plant, transportation costs, loading and unloading costs, and storage.

The salvage value of contractor's machinery is variable, and depends on the kind of machinery, the condition it is in, and the demand for this machinery at the time it is placed on the market.

Depreciation costs are comparatively large because of excessive wear and tear, obsolescence, lack of care, etc., which tend to

shorten the useful life of the equipment. The straight-line method of depreciation apparently is the most suitable method for contractor's equipment. In this method, the yearly (or monthly) depreciation is equal to the difference between the total first cost and salvage value divided by the assumed "life" of the equipment in years (or months).

The ownership costs of equipment are usually computed on a monthly basis. The cost for one piece of equipment for any one job is found by multiplying the monthly rate by the total time that this equipment is held available for the job.

The contractor should keep complete cost records of all equipment owned or rented. Many contractors prefer some form of card records or loose-leaf book records.

When using the Associated General Contractor Method (Appendix B), note that the cost data given includes depreciation; overhauling, major repairs, and painting; interest, taxes, storage, and insurance; ownership total expense; average use in months per year; and expense per working month. The daily rate is equal to the monthly rate divided by 30. Note that other costs items must be added. Some such items are transportation to and from the job, erection and removal, moves, operation, and minor repairs.

Rental Costs.—The total cost of a rented piece of equipment for any one job will depend upon such items as monthly rental cost, months rented, transportation, erection and removal, moves, operation, and minor repairs. Some idea of the rental rates and what they include may be obtained from Appendix C. In some special cases, rental costs include all costs; in other cases, the rental costs may or may not include such items as operating costs, wages of operator, minor (as well as major) repairs and, transportation.

Rentals are usually quoted by the month. The rental cost is found by multiplying the monthly rental rate by the total time in months that the equipment is held available for the job. Rentals are usually based on one shift per day, the usual shift being 8 hr. or less. Rental prices are increased when machines are operated more than 8 hr. per day or when more than one shift is used. The rental rate for the second shift is about 50 per cent of that for the first shift.

Sometimes the rental rates are based on the ownership costs according to the method suggested by the Associated General Contractors. Note that in such instances, an allowance should be included for profit and also for any expense items other than those stated and which must be paid for by the owner.

Small Tools.—On almost every construction job, the estimator must compute the costs of the small tools used as well as the costs of the larger tools and equipment. Such small tools are wheelbarrows, jacks, screws, dollies, wrenches, hammers, sledges, picks, crowbars, hoes, mauls, hose, shovels, lanterns, robes, and saws.

On most jobs, the various mechanics furnish all their small hand tools. On such jobs, the contractor may need a chest of miscellaneous tools. When the contractor has to furnish all the hand tools, the kind and number required must be estimated and their cost allowed for.

The "life" of small tools is usually taken as one year. Some tools wear out in a few months, and others may last several years. The losses due to breakage and disappearances are comparatively large.

8. Apportionment of Costs.—There are several ways of apportioning or allocating plant and equipment costs. For estimating purposes, cost computations are usually based on time when finding total costs. Then unit costs, based on any desired unit, are found by dividing the estimated total costs by the number of units.

The estimator may use a monthly rate or a daily rate based on the entire time that the equipment is available for the job. The daily rate may be for one or more shifts per day. Some estimators use hourly rates, basing these rates on the total time or on the operating time. Other estimators use two hourly rates, one when the equipment is idle, and the other when the equipment is operating. Any particular method is satisfactory provided that all cost items are included.

After the total plant and equipment costs for the job and for each kind of work have been estimated, the desired unit costs may be computed. When any piece of equipment is used on two or more kinds of work, the cost for each kind of work should be estimated. An example of the use of equipment for more

than one purpose would be the use of a tower and hoist in building construction for hoisting the concrete, the brick, the lumber, and various other materials.

There are many unit costs that are used by estimators. Some of these are cost per hour, cost per idle hour, cost per operating hour, cost per square foot of floor or other area, cost per cubic foot of space, cost per cubic yard, cost per square yard, cost per square of 100 sq. ft. of area, cost per 1,000 brick, tile, or block, cost per 1,000 ft. b.m. for lumber, cost per pound or per ton for steel, cost per fixture as for plumbing, cost per outlet as in electrical work, and cost per radiator as in steam and hot-water heating. Many of the various units have been mentioned in this text.

9. Procedure in Estimating Construction Plant.—The procedure to be followed when estimating construction plant and equipment may be summarized as follows:

1. Visit site.
2. Visualize work.
3. Select equipment.
4. Plan arrangement or layout.
5. Estimate time required, total, idle, and operating.
6. Estimate plant costs.
7. Check work.
8. Repeat procedure for each of other possible practical plant designs.
9. Compare costs of different plant designs, and select most desirable design.

CHAPTER XVIII

OVERHEAD AND PROFIT

1. Overhead.—Overhead costs may be said to include all the general costs of maintaining a contracting business plus such job costs as are not included in materials, labor, and equipment costs. Overhead costs are usually divided into general overhead, such as office and yard costs, and job overhead.

General overhead costs include the costs of maintaining an office, shop, and yard in which to do business. Such expenses are continuous, though they may vary somewhat with the amount of business done or with the number and size of the jobs.

Job-overhead costs are the overhead costs that vary with and are caused directly by the individual jobs.

Overhead costs are increasing and may be expected to increase for some years to come because of the social-security tax increases and because of the tendency of more states to require more and greater protection for the workmen especially in regard to compensation and personal liability.

2. General Overhead.—General overhead costs may be divided into general office, shop, and yard costs. The general overhead costs may vary from almost nothing, as for a small contractor who maintains no office, up to 8 to 15 per cent of the total business done. Average percentages may vary from about 2 to 8. The following lists will give an idea of the various items that may be included in general overhead costs. Almost any job will include several of these items, though no one job may include all of them.

General Office Costs

Rent	Interest
Heat	Taxes
Light	Salaries of general officers
Telephone	Wages of estimators
Telegraph	Wages of draftsmen
Stationery and supplies	Wages of clerks
Furniture and fixtures	Wages of stenographers

Some of the kinds of insurance are as follows:

General	Miscellaneous
Workmen's liability	Automobile
Public liability	Vehicle
Property damage	Boiler
Fire	Wind
Windstorm	Rain
Owner's contingent	Flood
Contractor's contingent	Earthquake
Workmen's compensation	Plate glass
Old age	Theft
Unemployment	Pay roll
Social security	Forgery
Structure	Elevator
Various contingencies	Use
	Occupancy

Interest.—On most construction jobs, there may be interest payments, which payments should be included in the overhead.

Taxes.—If the contractor, instead of the owner, is required to pay taxes on a structure (say an office building, for example) during the construction period, such taxes should be included as an overhead cost.

Contingencies.—On practically every construction job, there will be certain cost items that were not foreseen (and in some cases could not be reasonably predicted) when the estimates were prepared. Most contractors include an allowance for contingencies in their estimate of overhead costs. On ordinary jobs, the percentage allowed for contingencies may be comparatively small.

4. Apportionment of Overhead.—There are various ways of apportioning the general overhead costs to the various jobs. No doubt the best way would be to charge the actual costs to each job, provided that such costs could be accurately estimated in each case.

The more common methods are to divide general overhead costs among the various jobs according to the estimated costs (materials, labor, and equipment) of the jobs or according to the estimated labor costs. In these methods, a certain percentage is added to the sum of the costs of materials, labor, and equipment, or to the labor cost, to care for the overhead costs. The percentage allowed is based on past costs and experiences and also to some extent on the probable business for the current year.

In some instances, estimators have divided the general overhead costs according to the number of jobs. In other instances, estimators have estimated the overhead costs according to the length of time required to complete a particular job.

The job-overhead costs may be estimated in detail and included with the estimates of materials, labor, and equipment when preparing the total estimated cost. Though this method is, perhaps, the most accurate method, the two common methods are to use selected percentages and to base the job-overhead costs either on the sum of materials, labor, and equipment costs, or else on labor costs alone. When selecting the percentages, consideration is given to such things as the kind of job, magnitude of work, probable difficulties to be encountered, and costs on previous jobs.

Many contractors do not divide their overhead costs into general- and job-overhead costs, but consider all overhead costs together. Then, for any particular job, they allow either a selected percentage of the sum of materials, labor, and equipment costs, or a percentage of labor costs alone. The percentage may vary from about 5 to 25 of the sum of materials, labor, and equipment costs, or from about 10 to 50 of labor costs alone.

5. Bonds.—There are many types and kinds of bonds. Only a few of the more common ones will be briefly described in this article. Unless otherwise specified, the contractor will be expected to pay the cost of the bonds. Such costs should be included in his overhead costs.

Bid Bond.—A bid or proposal bond is a bond submitted by the contractor with his bid as evidence that he will enter into the contract if the contract be tendered to him. Such a bond may take the place of a certified check. When the contract is awarded to a particular contractor, his bid bond or certified check is held until he signs the contract and submits his contract or performance bond. Then the bid bond or certified check is returned to him. The cost of a bid bond is nominal, usually being about $5.

Contract Bond.—A contract or performance bond is a bond submitted by the contractor after he has signed the contract. The purpose of such a bond is to guarantee the faithful fulfillment of the contract by the contractor. Contract bonds are of two kinds, construction and material supply. These bonds are sometimes called surety or guarantee bonds.

A construction bond guarantees the faithful performance of the construction work by the contractor. The amount of the bond may vary from about 20 to 100 per cent of the contract price. The cost or premium of such a bond varies from time to time and also with the kind of work. The premium is usually based on the contract price rather than upon the amount of the bond. For ordinary construction work, which may be completed in about 2 years or less, the premium is about 1.5 per cent of the contract price. For longer times, an additional premium of about 0.75 per cent per year is charged. The premium for street and highway work varies from about 0.75 to 1.5 per cent per year. Probably a premium of about 1 to 1.5 per cent per year would be the average for most work.

A material supply bond is given by a material dealer to ensure the proper deliveries of materials in regard to time, quantity, and quality. The premiums on these bonds may vary from about 0.25 per cent of the contract price for materials delivered from stock to 0.75 per cent for materials specially designed or ordered.

Maintenance Bond.—Sometimes the contractor is required to maintain the building, pavement, or other structure for a period of time after its completion. The maintenance bond is submitted by the contractor as a guarantee that he will care for the maintenance work needed. The premium on a maintenance bond may be computed on the contract price or upon the value of the bond. When based on contract prices, the premium rates may vary from about 0.15 to 0.75 per cent.

Fidelity Bond.—A fidelity bond is one given by an employee to his employer to protect the employer from loss of money through any negligent action of the employee. Each employee who may be required to handle any considerable sum or sums of money should be placed under bond. The premium for a fidelity bond is nominal. This premium is usually paid by the employer and included in his overhead costs.

6. Insurance.—Insurance can be secured to cover practically every operation, condition, or risk in almost every kind of construction work. The different kinds of insurance and the amount of each kind will depend upon the conditions of the particular job, the law, the contract requirements, and upon the desires and experiences of the contractor. The estimator should determine the kinds, amounts, and other details of the kinds of insur-

ance required by law in the state or locality in which the particular construction work is to be done.

A number of different kinds of insurance are listed in Art. 3 of this chapter on Job Overhead. The estimator should consult a reliable insurance agency for information concerning correct insurance rates for the locality in which any particular job is located.

No attempt will be made in this article to describe all the kinds of insurance that may be secured. Only a few of the more common kinds of insurance will be briefly described.

Workmen's Compensation Insurance.—The rates charged for this insurance are based upon the pay roll and vary in different states, for different kinds of work, at different times, and for different contractors. Base rates in force on Apr. 1, 1946, are given in Appendix E. Note that these base rates vary from about 2 per cent or less for electric wiring up to as much as 28 per cent for structural-iron and steel erectors in New York, and up to 28 per cent for workers wrecking buildings in Wisconsin. The contractor should be careful to classify his workmen correctly.

Social Security, Old-age Retirement, and Unemployment Insurance.—Contractors are in general subject to the Federal Social Security Act, the Federal Unemployment Tax Act, and also to various state laws and regulations.

Under the Social Security Act, assessments are made on the wages paid the workmen. The employer pays part and the workmen part. The assessments against the employer in 1946 are 1 per cent of all wages paid. The assessments against the employee in 1946 are 1 per cent of all wages paid, the assessments being deducted from the employee's wage.

These percentages apply to all salaries and wages paid employees up to a total of $3,000 per year per person.

Many states also levy pay-roll taxes. The rates vary in different states. In many states, part of such state taxes may be credited against Federal Social Security Taxes.

Employer's Liability Insurance.—This is insurance taken out by the contractor or employer to care for his liability in regard to

accidents and injuries to employees. The rates are usually based on the pay roll and vary for different occupations and from time to time. The minimum limits are usually $5,000 per person and $10,000 per accident when two or more persons are involved. Higher limits are often desirable.

Public Liability Insurance.—This insurance is taken out by the contractor as a protection from loss caused by accidents to any person or persons not in his employment. The rates may vary with the pay roll, kind of structure, policy limits, and amount of policy. Minimum limits are usually the same as for employer's liability insurance. When based on pay roll, the cost may vary from about $0.25 to $0.50 per $100 of pay roll.

Automobile and Vehicle Insurance.—If a contractor owns and operates automobiles, trucks, and other vehicles, he should take out insurance covering these vehicles and their operation. Rates may vary from about $25 and up per vehicle, depending on the conditions in the particular policy selected.

Property-damage Insurance.—The contractor on some jobs should take out insurance against claims arising from possible damage to other property. Such insurance is especially desirable when the proposed work may cause damage to an adjoining structure, such as damage caused by the settlement of the foundations of a structure on an adjoining lot when the excavation is made for a new building. The rates for property-damage insurance will vary with the risks involved.

Contingent Insurance.—Contingent insurance may be taken out by the contractor to protect the owner during the construction period. Such insurance is called owner's contingent insurance. Rates are usually based upon the kind and cost of the job.

Another kind of contingent insurance is that taken out by the contractor to protect him from claims resulting from any acts of his subcontractors. This insurance is called contractor's contingent insurance. Rates are usually based upon the kind and cost of the job.

Fire Insurance.—The fire insurance should cover the structure itself (if inflammable), scaffolding, sheds, temporary structures, and all materials, equipment, and tools on the property either in the structure, in temporary structures and sheds, or upon the lot. Fire insurance may cost $0.30 to $0.70 per year per $100 of valuation.

Wind and Rain Insurance.—Such insurance, often called tornado or windstorm insurance, should be carried if there is any possibility of the structure being damaged by wind and rain. Rates for this kind of insurance are usually less than fire-insurance rates.

Structure or Blanket Insurance.—Some insurance companies issue what is known as structure or blanket insurance in which one policy covers all the protection required, and which formerly required several policies of various kinds. When taking out structure or blanket insurance, the contractor must inform himself of all the different hazards covered and the amounts. Rates for blanket insurance are usually appreciably less than the sum of the rates for the different kinds of insurance considered separately.

7. Profit.—The amount of profit is usually expressed as a percentage of the sum of the estimated costs of materials, labor, equipment, and overhead. The percentage allowed for profit will vary according to the kind of the job, the amount involved, and the time required for completion. Usually a larger percentage is allowed for smaller and more hazardous jobs. The percentage allowed for profit will also depend upon the contractor's desire for the particular work, what he thinks is fair, and what he thinks he can get.

The percentage allowed for profit may vary from about 5 to 25 per cent. For small-sized and hazardous jobs, 20 to 25 per cent may be used; 15 to 20 per cent for jobs of medium size and which are somewhat less hazardous; 10 to 15 per cent for large jobs when the hazards are not great; from 5 to 10 per cent for very large jobs when the hazards are small.

CHAPTER XIX

COMPLETE ESTIMATES

1. Complete Estimates.—A complete cost estimate, especially from an owner's viewpoint, contains many items other than those included in the main and subcontracts. Many people think that the total cost of a structure, say an office building for example, includes only the costs of the land and of the main and subcontracts. There are many other cost items that may be included.

A discussion of the costs of several of these items is given in the following articles of this chapter. An attempt has been made to include all the main items in the discussion. However, there may be jobs on which other items should be included. Likewise, on many jobs all items mentioned may not be included.

2. Land.—There are several items of cost other than the first cost or price of the land, which an owner may be required to pay. The cost of the land will include one or more of the following items:

First cost. Price paid to former owner.

Real-estate commissions. These are usually, but not always, paid by the seller.

Survey. A survey of the land by a responsible land surveyor is often advisable to determine if the actual boundaries agree with those given in the deed.

Deed. The deed should be examined by a competent lawyer to see if it has been correctly drawn.

Title investigation. Frequently, the seller is required to provide an abstract of title or other proof of ownership or title to the land. This abstract should be examined by a competent lawyer to see if it is correct and if the seller has a clear title to the land and can transfer a clear title to the buyer.

Zoning. Check on zoning restrictions, if any.

Back taxes. Determine if all regular taxes have been paid.

Special taxes. Such as sewer, water, and street-improvement taxes. Determine number and amount of installments to be paid.

3. Legal Expenses.—On practically every construction job, except possibly the smallest and simplest, the owner should have a competent lawyer examine and pass on all contracts and agreements before the owner signs them. Legal advice is important on all items that may involve possible litigation. The owner often retains the same lawyer, or firm of lawyers, to look after all the legal affairs connected with any particular construction job.

4. Architectural and Engineering Fees.—These fees are often divided into two parts, one for the preparation of designs, plans, and specifications, and the other for supervision during construction. The fees charged for designs, plans, and specifications may range from about 2 to 12 per cent of the estimated cost of the structure, depending upon the work involved. The fees charged for supervision of the work during construction may vary from 2 to 15 per cent, depending on the particular job and the amount of supervision (general or detailed) desired.

5. Main Contract.—Sometimes the main contract includes all the work of construction. On other jobs, only the general or main parts of the job are included and subcontracts are let for the specialized work. For example, on a building job, the main contract may include all the work to be done by the general and subcontractors, or it may include only the work to be done by the general contractor. The owner should know what work is to be done by the main or general contractor and what work by each of the subcontractors. He must also know whether or not the general contract includes work by the subcontractors.

6. Subcontracts.—On many construction jobs, the specialized work is let to qualified subcontractors. These subcontractors may work under the general contractor and be responsible directly to him, or they may not be under the main contractor but may be responsible directly to the architect, engineer, owner, or owner's agent, as the case may be.

For example, in the construction of a building, subcontracts may be let for the plumbing, heating and air conditioning, electric wiring, and painting and decorating.

For another example, in the construction of a bridge a subcontractor may build the foundations and piers, another may build the approaches, and the main contractor constructs the bridge on the prepared foundations.

7. Extras.—On practically every job, there will be some extras and contingencies that are not covered in the main and subcontracts. These contracts usually include clauses in regard to extras and their cost. On many construction jobs, the extras may cost 2 to 10 per cent or more of the sum of the main and subcontracts. Consequently, the owner should consult with his architect and engineer and make a reasonable allowance for extras for the particular job.

8. Permits and Inspection Fees.—On many jobs, permits must be obtained for doing certain kinds of work and for making connections such as for water and electricity. Many kinds of construction work require inspections by various government, state, and local officials and inspectors.

The cost of all permits and inspections will be usually charged against the owner, and he will be required to pay them unless provision for their payment by the contractors concerned is provided for in the main and subcontracts.

9. Surety Bonds.—On most large jobs, each contractor is required to give a surety bond for the successful completion of his work according to the contract and specifications. The individual *contractors are usually required to pay for these bonds.* However, if the contract in question does not state that the contractor is to pay the premium, the contractor may pay it and add the cost as an extra.

10. Financing.—When the owner does not have sufficient funds available to pay for the entire costs of construction, he must make arrangements to obtain the needed funds from some other source. The bank, trust company, or finance company involved usually makes a charge for the service of securing the necessary funds. This charge usually ranges from about 2 to 5 per cent of the funds provided, though the charge may be more in times when money is difficult to obtain, when the amount required is more than about half to two-thirds the value of the job, when the owner's credit is bad, or when the apparent risk is greater.

Sometimes the general contractor arranges for the financing as well as for the construction of the job. When this is the case, the general contractor includes a financing charge with his bid.

11. Insurance.—Though the contractors who do the work are usually required to provide all insurance that may be deemed

necessary, the owner may be also held responsible in many cases. Consequently, it may be advisable for the owner to take out insurance, such as public liability, personal injury, fire, tornado, or property damage, for his own protection. On a large building construction job, the cost of such insurance may be an appreciable item.

12. Interest.—Interest charges during construction should always be allowed. When the time required is a year or more and the amounts paid the contractors before the final completion of the job are large, the construction interest charges may be considerable. For example, if the time required to construct a $1,000,000 building was 2 years and the contractors received partial payments up to 90 per cent of the cost, the interest charges during the construction period would be approximately $33,000, by assuming interest rates at 5 per cent per annum.

13. Taxes.—On practically every private construction job that extends over one tax assessing and paying time, some taxes will have to be paid. The amount of taxes, on a new building for example, will depend on the tax rate, the assessed valuation of the land, and the assessed valuation of the portion of the structure erected at the time the assessment was made. This particular valuation of the structure will include all materials actually installed in the structure and may or may not include part or all the materials delivered at the site but not yet incorporated in the structure.

14. Miscellaneous.—On most large jobs, there will be a number of miscellaneous expenses that an owner may have to pay. Some such items are stenographic services, transportation to and from the job for owner's inspections, and entertainment (if the owner deems it necessary to entertain the architect, engineer, contractor, or others). Though not large, the sum total of such items should be allowed for.

15. Summary.—The items that may be included in a complete estimate may be summarized somewhat as follows:

Land.
Legal expenses.
Architectural and engineering fees and commissions.
Main contract.
Subcontracts.
Extras.

Permits and inspection fees.
Surety bonds.
Financing costs.
Insurance, owner's.
Interest, during construction.
Taxes, during construction.
Miscellaneous items.
Total.

CHAPTER XX

APPROXIMATE ESTIMATES

1. Approximate Estimates.—The only safe and sure method of estimating costs is to take off the actual quantities of materials, judge the labor-hours required, and use the prevailing prices for labor and materials. However, many experienced estimators, when estimating the costs of certain types of structures, make use of short cuts or approximations (1) to obtain the approximate cost in a short time, (2) to check roughly the costs found by more accurate methods, and (3) to compare the costs of like structures erected at other times and places.

Costs estimated by a short-cut or approximate method are approximate only. Their value depends upon the judgment, skill, and experience of the estimator, upon the care with which the estimates are prepared, and upon the correctness of the prices used.

2. Estimating Building Costs by the Square Foot of Floor Area Method.—The method of estimating by the square foot of floor area is applicable to such structures as office buildings, schools, mills, warehouses, factories, hospitals, churches, stores, residences, and garages. This method is useful in comparing the costs of different buildings of the same type or kind where the floor area is important, as in office buildings and factories. This method is also useful in determining the costs per person, as in schools, hospitals, and churches.

There are several variations of the method for estimating building costs by the square feet of floor area. One variation is to allow a certain price per square foot for each floor, including the basement, attic, and roof. Another variation is to use different unit cost prices for the basement floor, other floors, and roof. A third variation is to use different unit cost prices for the different floors and have the price for the lower floor include the cost of the basement and foundations. The price for the upper floor should include the cost of the roof. A fourth method

is to use the same unit cost price for all usable floors, omitting the roof area or both the roof and basement areas. This fourth method is preferred by many estimators. Consequently, it is important to state just what is included in the unit cost price used in the estimate.

The following illustrative example shows the effect on the computed cost per square foot by using the different methods.

3. Illustrative Estimate.—A certain building is 40 by 60 ft. in size and consists of a basement; first, second, and third floors; and attic. The cost of the building was $44,270.

Compute the cost per square foot of the building:

1. Based on total area of three floors, basement, attic, and roof.
2. Based on total area of three floors, basement, and roof, assuming basement to cost 0.60 per cent of the cost of the first floor, attic floor to cost 0.40 per cent of the cost of the first floor, roof to cost 0.50 per cent of the cost of the first floor, and first, second, and third floors to have equal costs.
3. Based on area of the three floors, assuming the cost of the first floor to include cost of basement and to be 1.60 times the cost of the second floor, and assuming the cost of the third floor to include cost of attic floor and roof and to be 1.90 times the cost of the second floor.
4. Based on total area of the three floors only.

Solutions.—1.

Basement area	=	2,400 sq. ft.
First-floor area	=	2,400 sq. ft.
Second-floor area	=	2,400 sq. ft.
Third-floor area	=	2,400 sq. ft.
Attic-floor area	=	2,400 sq. ft.
Roof (horizontal) area	=	2,400 sq. ft.
Total	=	14,400 sq. ft.

$$\text{Cost per square foot} = \frac{\$44,270}{14,400} = \$3.08$$

2.

Basement area, equivalent = 2,400 × 0.60	=	1,440 sq. ft.
First floor	=	2,400 sq. ft.
Second floor.	=	2,400 sq. ft.
Third floor	=	2,400 sq. ft.
Attic floor, equivalent = 2,400 × 0.40	=	960 sq. ft.
Roof, equivalent = 2,400 × 0.50	=	1,200 sq. ft.
Total equivalent area	=	10,800 sq. ft.

Cost per square foot, first, second, and third floors
= $44,270/10,800 = $4.10

Cost per square foot, basement = $4.10 × 0.60 = $2.46

Cost per square foot, attic = $4.10 × 0.40 = $1.64

Cost per square foot, roof = $4.10 × 0.50 = $2.05

3.

First floor, equivalent = 2,400 × 1.60	=	3,840 sq. ft.
Second floor	=	2,400 sq. ft.
Third floor, equivalent = 2,400 × 1.90	=	4,560 sq. ft.
Total equivalent	=	10,800 sq. ft.

Cost per square foot, second floor = \$44,270/10,800 = \$4.10
Cost per square foot, first floor = \$4.10 × 1.60 = \$6.56
Cost per square foot, third floor = \$4.10 × 1.90 = \$7.79

4.

First-floor area	=	2,400 sq. ft.
Second-floor area	=	2,400 sq. ft.
Third-floor area	=	2,400 sq. ft.
Total area, three floors	=	7,200 sq. ft.

Cost per square foot = \$44,270/7,200 = \$6.16

4. Estimating Building Costs by the Cubic Foot of Volume Method.—The method of estimating building costs by the cubic foot of volume is more accurate, in general, than the method of estimating costs by the square foot of floor area. Buildings of different types and different kinds of construction require different cost prices per cubic foot.

The best way of estimating costs by the cubic-foot method is to find the total volume of the building in cubic feet, and multiply this volume by a selected price per cubic foot for this particular class and type of building.

Another way is to use a certain unit cost per cubic foot for the parts of the building that are more expensively finished, and to use lower prices for the parts that are more cheaply or less completely finished. For example, in a residence one unit price would be used for the basement, attic, and attached garage, and another unit price for the living room, dining room, kitchen, and bedrooms.

A third way is to consider only half or two-thirds of the volume of the basement, attic, and attached garage, when computing the volume of a residence, and then to use the same cost price per cubic foot for all parts of the building.

The American Institute of Architects, Washington, D. C., in the *A.I.A. Document* 239, recommends the following:

The cubic content (cube or cubage) of a building is the actual cubic space enclosed within the outer surfaces of the outside or

enclosing walls and contained between the outer surfaces of the roof and 6 in. below the finished surfaces of the lowest floors.

The preceding definition requires the cube of dormers, penthouses, vaults, pits, enclosed porches, and other enclosed appendages to be included as a part of the cube of the building. It does not include the cube of courts or light shafts open at the top, or the cube of outside steps, cornices, parapets, or open porches or loggias.

The following items shall be listed separately:

1. Cube of enclosed courts or light shafts open at the top, measured from outside face of enclosing walls and from 6 in. below the finished floor or paving to top of enclosing walls.

2. Cube of open porches measured from outside face of wall, outside face of columns, finished floor, and finished roof.

It is recommended that the following items also be listed separately:

a. Square feet of area of all stoops, balconies, and terraces.

b. Memoranda, or brief description, of caissons, piling, special foundations, or features, if any.

The following illustrative example shows how the costs per cubic foot may be found by two methods. The first method is recommended.

5. Illustrative Estimate.—A certain building is 40 by 60 ft. in size and consists of basement; first, second, and third floors; and attic. The heights, including floor thicknesses, are 8.5, 10, 9, and 9 ft. for the basement, and first, second, and third floors, respectively. The average height of the attic is 7.5 ft. The cost of the building was $44,270.

1. Compute the cost per cubic foot based on the total volume of the building in cubic feet.

2. Compute the cost per cubic foot, allowing 60 per cent for the basement, full value for the three stories, and 50 per cent for the attic.

Solution.—1. Cubical contents:

$$\begin{array}{lll}
\text{Basement} & = 40 \times 60 \times 8.5 = & 20{,}400 \text{ cu. ft.} \\
\text{First floor} & = 40 \times 60 \times 10 = & 24{,}000 \text{ cu. ft.} \\
\text{Second floor} & = 40 \times 60 \times 9 = & 21{,}600 \text{ cu. ft.} \\
\text{Third floor} & = 40 \times 60 \times 9 = & 21{,}600 \text{ cu. ft.} \\
\text{Attic} & = 40 \times 60 \times 7.5 = & \underline{18{,}000} \text{ cu. ft.} \\
\text{Total} & = & 105{,}600 \text{ cu. ft.}
\end{array}$$

Cost per cubic foot = \$44,270/105,600 = \$0.42

2. Equivalent cubical contents:

Basement	$= 40 \times 60 \times 8.5 \times 0.60$	= 12,240 cu. ft.
First floor	$= 40 \times 60 \times 10$	= 24,000 cu. ft.
Second floor	$= 40 \times 60 \times 9$	= 21,600 cu. ft.
Third floor	$= 40 \times 60 \times 9$	= 21,600 cu. ft.
Attic	$= 40 \times 60 \times 7.5 \times 0.50$	= 9,000 cu. ft.
Total equivalent		= 88,440 cu. ft.

Cost per cubic foot, based on allowances given,

$$= \$44,270/88,440 = \$0.50$$

6. Panel Method for Buildings.—In the panel method of estimating building costs, the costs of each kind of the "panels" (wall and floor) are computed separately, and then these costs are multiplied by the respective number of panels of each kind. There are about as many variations of the panel method as there are different kinds of buildings.

The panel costs usually include the items of materials, labor, and equipment. Heating and air conditioning, plumbing, wiring, painting and decorating are added later as separate items, though painting and decorating may be included in the panel costs. Overhead and profit for the whole structure are usually added later as separate items. However, when dealing with some customers, it may be advisable for the contractor to include the overhead and profit when computing his panel costs. Then the customer may be shown how the numbers of different kinds of panels are found, and how these numbers are multiplied by their respective costs. In this way, the customer does not know what the charges are for overhead and profit, unless the contractor shows how the details of the unit panel costs are prepared.

Some estimators think the panel method is better than the square-foot-of-floor-area method or the cubic-foot-of-volume method because the panel method takes into consideration the variations in the ratios of floor and roof areas to wall areas that practically always occur with changes in the shapes and sizes of buildings.

7. Panel Method for Residences and Small Buildings of Frame Construction.—The panel method for estimating building costs may be applied to residences and other small buildings of frame construction by obtaining the cost per square foot, or per

square of 100 sq. ft., for the floors (basement, first, second, attic, etc.) and for the roof, allowing for such things as the overhang, eaves, and valleys. For the exterior walls and partitions, the costs may be computed per square foot or per square of 100 sq. ft. of wall area. However, for wooden-frame construction most estimators prefer to consider a wall panel as the area whose width is equal to the distance center to center of studs (usually 16 in.) and whose height is equal to that of one story, often from 8 to 10 ft. There are several ways of allowing for the windows and doors in the wall panels. The simplest way is to compute the cost of a plain wall panel and add certain amounts for each window and door. Another way is to compute the cost of a wall panel containing a window or a door, as the case may be.

For a wooden-frame building, such as a residence, the following kinds of panels may need to be considered:

Basement-floor panel, usually concrete.

First-floor panel, finish flooring, paper or felt, rough flooring, joists and bridging, lath and plaster.

Second-floor panel, finish flooring, paper or felt, rough flooring, joists and bridging, lath and plaster.

Attic-floor panel, rough flooring, insulation, joists and bridging, lath and plaster.

Roof panel, roofing (shingles), paper, sheathing, rafters, insulation, and allowances for eaves, metalwork, etc.

Basement wall panel, usually concrete, furring, lath and plaster (if any), windows, doors, etc.

Exterior plain wall panel, siding, paper, sheathing, insulation, studs, lath and plaster, baseboards, molds, etc.

Exterior wall panel with window, same as for exterior plain wall panel with allowance for window and trim.

Exterior wall panel with door, same as for exterior plain wall panel with allowance for door and trim.

Interior plain wall or partition panel, usually two layers of lath and plaster, studs, baseboards, molds, etc.

Interior wall or partition panel with door, same as for plain interior panel with allowance for door and trim.

For a brick veneer over a wooden frame, the exterior panels would include brick instead of siding.

For a stucco exterior on a wooden frame, the exterior panels would include lath and stucco instead of siding.

Wall panels containing doors and windows usually cost more than plain wall panels.

Items such as stairs, steps, and porches must be added as separate items.

When the cost for each kind of panel is known, it is only necessary to count the number of panels of each kind and compute the total costs. For estimating residences, it is usually advisable to include overhead and profit in the panel costs. Painting and decorating, heating, plumbing, wiring, and electric fixtures are usually added as separate items.

The contractor can prepare cost estimates for typical wall, floor, and roof panels of different kinds of construction, using different kinds and qualities of materials, and then can use these panel costs when preparing preliminary estimates for customers. Changes in the prices of materials and in wages must be allowed for as they occur.

8. Panel Method for Industrial and Commercial Buildings.—The panel method may be used for large buildings such as warehouses, factories, and office buildings of different kinds of construction such as wooden-mill construction, steel-mill construction, steel-frame buildings, and reinforced concrete construction.

The panel estimate may be divided into the following items:

1. Columns. Including foundations and necessary excavation.
   a. Exterior.
   b. Interior.
2. Floors. Including basement floor and excavation.
3. Roof.
4. Trusses. Such as roof trusses.
5. Exterior walls, including doors and windows.
   a. Basement walls, including footings and excavation.
   b. Wall panels for each story above basement.
   c. Parapet walls, as around roof.
6. Interior or partition walls, including doors.
7. Stairs and stair walls.
8. Elevators.
9. Heating and air conditioning.
10. Plumbing.
11. Electrical work.

12. Sprinkler systems (if any).
13. Painting and decorating.
14. Contingencies.
15. Overhead.
16. Profit.
17. Summary or total estimate.

When preparing the estimate, the items listed need not necessarily be taken in the order given. Some items may be omitted or combined with others, and other items added as desired.

For example, in estimating the cost of a two-story and basement warehouse, 60 by 100 ft. in area with columns spaced 20 ft. on centers, there may be

16 exterior columns.
8 interior columns.
15 basement-floor panels.
15 first-floor panels.
15 second-floor panels.
15 roof-floor panels.
16 exterior-basement-wall panels.
32 exterior-wall panels.
16 parapet-wall panels.
18 partition-wall panels.
7 sets of stairs.
1 elevator.
1 sprinkling system for three floors.

Some of the floor panels may be modified because of stairs and elevator. Allowances must be made for heating, ventilation, plumbing, electrical work, painting, and other items and contingencies as required by the plans and specifications. Overhead and profit must be included.

9. Bay Method for Buildings.—When a building consists of several equal bays, the cost of the building may be estimated by estimating the cost of one bay and then multiplying this cost by the number of bays.

Allowances must be made for end walls, entrances, and other items that are not included in a typical bay. For example, an exterior corner bay will have two exterior walls, an exterior side bay will have one exterior wall, all bays may have one or more interior walls or partitions, some bays may have stairs and stair

walls, and some may contain elevator shafts. Special items not included in a typical bay may be roof trusses, other trusses or girders, elevators, extra columns and beams, and also any omissions of columns, beams, and slabs.

The bay method of estimating buildings is usually not so accurate as the panel method but may be more accurate than the square foot of floor area or cubic foot of volume methods.

10. Comparative Costs.—When comparing unit costs of structures, consideration must be given to the use of the structure (bridge, residence, store, warehouse, etc.), kind of construction (truss bridge, wooden-frame residence, steel-frame building, reinforced concrete building, etc.), quality of construction (cheap, medium, good), locality (city, village, country, eastern, southern, etc.), and year and time of year. If the classification idea is carried farther and buildings only are considered, the buildings may be classified as follows:

Use or occupancy. Residence, apartment, store, warehouse, office, school, hospital, theater, garage.

Kind of construction. Wooden frame, siding, brick or stone veneer, stucco, steel frame, reinforced concrete, steel mill, wooden mill, brick, stone, etc. Insulated, noninsulated. Fireproof, fire resisting, semi-fire resisting, non-fire resisting.

Quality of construction. Cheap, medium, good, very good.

Foundations. Kind of soil, soft, medium, hard, loam, sand, gravel, rock, under water. Simple or combined footings, mat or raft foundations, bearing or sheet piling, piers, open well or caisson.

Location. City, village, country, eastern, western, southern, northern. Wet, medium, or dry climate.

Time. Year. Summer or winter.

Other kinds of structures may be classified in somewhat similar ways.

The unit on which the comparative costs are based must be suitable for the kind of structure considered and the use to which the structure is to be put. Some examples follow:

Bridges, span in feet.

Pavements, area in square yards.

Excavation, cubic yards.

Concrete, cubic feet, or cubic yards.

Buildings, square feet of floor area or cubic feet of volume.

Schools, per pupil, per square foot of floor area.

Office buildings, per office, per room, per square foot of rentable floor space.

Apartment buildings, per apartment, per room, per square foot of floor area, per cubic foot of volume.

Theaters, per seat.

Stadium, per seat.

Grain elevators, per bushel of capacity.

Storage warehouse, per cubic foot of storage space.

Manufacturing buildings, per unit of daily output, per square foot of available floor space.

Automobile factory, per car.

Power plant, capacity in horsepower or kilowatts.

Hospitals, per bed.

Hotels, per room.

Store, per square foot of rentable floor area.

11. Range of Unit Costs.—Unit costs vary greatly for different buildings. For residences, the cost per room may range from about $800 for a cheaply constructed frame dwelling, to $1,200 to $2,100 for medium construction with insulated walls, to about $7,000 for the finest construction with insulated masonry walls, large rooms, plate-glass windows, special wood trim, special painting and decorating, elaborate plumbing fixtures, and heating and air-conditioning plant with separate room controls. For apartment buildings, the cost per apartment may vary from about $2,500 to $13,000, depending on the number of rooms in the apartment, size of rooms, and quality of construction. The cost per room may range from about $1,200 to $2,500. For hotels, the cost per room may range from about $1,500 to $4,000, depending on the kind of construction, size of building, and space allowed for offices, lobby, dining room, etc. The cost per seat in a theater or auditorium may range from about $60 to $400. The cost of a school per pupil may range from about $200 to $1,300 depending on the kind and quality of construction and the space allowed per pupil. For an office building, the cost per room may range from $900 to $2,100, depending on the kind and quality of construction and the size of the rooms. The cost per seat in a stadium may range from about $3 to $40, depending upon the kind of construction, the cheaper price being for con-

struction on a hill side or the sides of a valley, and the higher price for a structure built above the ground level and of steel or reinforced concrete with exterior walls of brick, for example.

Panel Costs.—The cost per panel for a two-story and attic wood-frame residence may range about as follows:

Basement-wall panel, 16 in. by 8 ft	$ 6–$14
Outside-wall panel, plain, 16 in. by 9 ft	6– 15
Outside-wall panel with window, 16 in. by 9 ft	11– 27
Outside-wall panel with door, 16 in. by 9 ft	13– 33
Inside-wall panel, plain, 16 in. by 8 ft. 6 in	5– 11
Inside-wall panel with door, 16 in. by 8 ft. 6 in	9– 21
Basement floor, concrete, per square of 100 sq. ft	18– 40
First floor, per square, 100 sq. ft	40–100
Second floor, per square, 100 sq. ft	40–105
Attic floor, per square, 100 sq. ft	35– 70
Roof, per square, 100 sq. ft., horizontal projection	35–100

Outside-wall construction consists of 2 by 4 studs, lath, plaster and trim on the inside, and insulation (sheathing) paper and wood siding on the outside. Painting is not included.

Inside-wall construction consists of 2 by 4 studs with lath plaster and trim on each side.

First floor consists of joists, bridging, rough flooring, paper or felt, finish flooring.

Second floor consists of joists and bridging, lath and plaster below, and rough flooring, paper or felt, and finish flooring above.

Attic floor consists of joists and bridging, lath and plaster below, insulation, and rough flooring.

Roof consists of rafters, sheathing, paper, and asphalt shingles.

Painting and decorating, heating, plumbing, and electrical work are not included. However, labor, materials, equipment, overhead, and profit are included.

Square-foot Costs.—The costs per square foot of floor area for buildings will vary greatly, depending on the kind of building, method of construction and quality of construction. The cost per square foot is usually found by dividing the total cost by the total floor area. The total floor area is found by finding the area of one floor, using outside dimensions of walls, and multiplying by the number of floors. No deductions are made for openings.

Approximate costs (1946) may range as follows:

Kind of Building	Cost per Square Foot
Frame residences, cheap construction	\$ 4–\$ 7
Medium construction	8– 12
Good construction	12– 17
Very good construction	18– 26
Apartment buildings, medium construction	4– 8
Good construction	8– 12
Office buildings	6– 12
Stores	5– 10
Bank buildings	9– 18
Schools	4– 10
Industrial buildings	
Steel mill, 1 or 1½ stories	2– 5
Wooden mill, 2 to 6 stories	3– 8
Steel frame, multistoried	3– 10
Reinforced concrete frame, multistoried	3– 10

These costs per square foot of floor area are very approximate. They will vary considerably with buildings of different sizes, shapes, kinds of construction, quality, locality, and time.

Cubic-foot Costs.—Building costs per cubic foot vary greatly, depending on the kind of building and methods and quality of construction. The number of cubic feet are usually computed according to the method recommended by the American Institute of Architects and described previously in this chapter.

Approximate building costs (1946) may range as follows:

Kind of Building	Cost per Cubic Foot
Frame residences, cheap construction	\$0.25–\$0.40
Medium construction	0.30– 0.50
Good construction	0.45– 0.65
Very good construction	0.60– 0.90
Apartment building, medium construction	0.30– 0.45
Good construction	0.40– 0.65
Office buildings	0.45– 0.90
Stores	0.35– 0.75
Bank buildings	0.55– 1.20
Schools	0.20– 0.65
Industrial buildings	
Steel mill, 1 or 1½ stories	0.20– 0.45
Wooden mill, 2 to 6 stories	0.20– 0.50
Steel frame, multistoried	0 20– 0 50
Reinforced concrete frame, multistoried	0.25– 0 60

These costs per cubic foot are approximate only and will vary greatly with buildings of different shapes and sizes, kind and quality of construction, locality and time. Fireproof construction will cost 10 to 15 per cent more than fire-resisting construction.

12. Distribution of Costs.—There are many ways of distributing or "breaking down" the total cost of a structure. The cost may be divided into materials, labor, equipment, overhead, and profit for the entire structure, or the costs may be distributed according to the different kinds of work, such as foundations, framing, exterior and interior finish, mechanical trades, and painting and decorating for a building.

Approximate costs, expressed as percentages of the total, for materials, labor, overhead and equipment, and profit for several different kinds of construction work are approximately as follows (United States Construction Census Reports):

Type of construction	Percentage of total costs			
	Materials	Labor	Overhead and equipment	Profit
All classes	43.8	30.7	18.0	7.5
All building	43.7	31.5	15.3	9.5
Building, commercial	41.2	32.0	16.7	9.9
Building, manufacturing	51.9	22.8	14.4	10.9
Building, residential	45.2	29.0	14.7	11.1
Highway	41.8	25.7	23.3	9.2
Street paving	42.3	24.7	23.0	10.0
Grading	8.8	39.3	40.3	11.6
Bridge and culvert	43.0	29.8	19.7	7.5
Sewer, gas, water, conduit	37.2	33.5	20.6	8.7
Dam and reservoir	32.2	32.0	22.8	13.0
Water works	43.5	27.7	21.3	7.5
Dredging, river and harbor	24.9	29.8	37.5	7.8
Levee	16.4	32.5	41.7	9.4
Railroad	28.3	37.2	24.1	10.4
Foundation	35.3	35.8	22.5	6.4
Subways	32.5	34.7	18.9	13.9

The costs, and percentages of total costs for various items, will vary considerably with the kind and quality of construction,

kind of building, and specification requirements. The following cost distributions are approximate only. They are included to give an idea of the various percentages.

The following table gives the distribution of costs for two residences:

Item	Two-story frame residence	
	Siding, per cent	Brick veneer, per cent
Excavation	1.5	1.5
Concrete work	11.0	11.0
Brick work	....	11.5
Carpentry and millwork	45.0	39.0
Lathing and plastering	10.0	6.0
Sheet metal	1.5	1.5
Tile work	3.0	3.0
Plumbing	9.0	8.0
Heating	7.0	8.0
Electrical	4.0	3.5
Painting	7.0	6.0
Finish hardware	1.0	1.0
Total	100.0	100.0
Total cost	$10,300	$12,900
Cost per cubic foot	$ 0.36	$ 0.39

The table on page 483 gives the cost distribution for some large apartment houses of fireproof construction.

A multistoried mercantile building with concrete foundations and steel frame was built in 1937 in New York City. Volume was 293,640 cu. ft. Floor area was 26,334 sq. ft. This building was well constructed, and was considerably better than the average industrial building. The cost distribution was obtained from the June 30, 1938, issue of the *Engineering News-Record.*

An industrial (heavy manufacturing) building erected in New York City in 1937 cost $77,700. The floor area was 14,600 sq. ft., giving a unit cost of $5.30 per square foot. The cubage was 278,000 cu. ft., giving a unit cost of $0.28 per cubic foot. The cost distribution was as shown on page 484.

For further information concerning construction costs, the reader is referred to such publications as the *Engineering News-Record*, various editions of *Construction Costs*, *American Architect*,

Apartment Houses*

Item	Percentage of cost for buildings				
	No. 1	No. 2	No. 3	No. 4	No. 5
Foundations, framework, concrete work......	11.6	13.9	25.4	17.8	8.8
Exterior work, roofing, partitions, carpentry framing........	28.0	25.2	20.4	22.1	27.2
Interior finishes, surfacing.......	24.6	21.8	15.4	15.7	20.1
Mechanical and electrical trades.	22.9	23.4	19.7	18.8	19.1
Equipment and miscellaneous...	7.1	8.6	7.9	15.7	12.6
Builder's and architect's fees.......	2.9	5.1	7.0	6.2	6.9
Financial charges.	2.9	2.0	4.2	3.7	5.3
Total............	100.0	100.0	100.0	100.0	100.0
Cubage, cubic feet.	2,400,000	2,800,000	13,200,000	12,550,000	8,950,000
Cost per cubic feet.	$0.42	$0.38	$0.47	$0.42	$0.35

* Abstracted from the 1937 Construction Costs.

Cost Distribution of Mercantile Building

Item	Percentage of total	Cost per cu. ft.	Cost per sq. ft.
Foundations........................	7	$0.049	$0.595
Structural steel........................	11	0.077	0.935
Masonry........................	12	0.084	1.020
Floor arches and finish...............	6	0.042	0.510
Elevators........................	7	0.049	0.595
Lath and plaster......................	6	0.042	0.510
Plumbing........................	7	0.049	0.595
Heating and ventilating...............	9	0.063	0.765
Air conditioning......................	10	0.070	0.850
Electrical........................	7	0.049	0.595
Miscellaneous........................	18	0.126	1.530
Total........................	100	$0.700	$8.500

Item	Percentage of Total Cost
Excavation, foundations, ground-floor slab, cement arches and finishes, structural steel, iron work	31.6
Brick masonry, coping, sills, sash, spandrel water proofing	13.4
Roofing, flashing, and skylights	5.8
Heating and ventilating (11 unit heaters)	6.4
Plumbing and sprinklers	9.1
Electrical work	7.7
Plastering and painting	2.8
Miscellaneous equipment, hardware, doors, carpentry	8.1
Administration, supervision, insurance, general expense, fees	15.1
Total	100.0

Building Age and National Builder, *American Contractor*, *American Builder*, and *Engineering and Contracting*.

13. Cost Indexes.—At the present time, there are many cost indexes available which give information in tabular or graphical form or both relating to various construction costs. These costs are usually given in percentage form, and are based on the costs of some certain year which are considered as 100 per cent. By the study and use of the cost indexes and by consideration of construction trends and price trends, an experienced estimator is enabled to bring the cost data for any year up to the present time. Then this cost data may be used in preparing estimates.

Perhaps the best known of the cost indexes are those published monthly in the *Engineering News-Record*. Most of these cost indexes are based upon the year 1913 or the year 1926, considering the year selected as 100 per cent.

The following is a list of some of the cost indexes available. Most of them are reported monthly.

General construction cost indexes:

Engineering News-Record Construction Cost Index. 1913 = 100
Engineering News-Record Construction Cost Index. 1926 = 100

Special building cost indexes:

Engineering News-Record Building Cost Index. 1913 = 100
Aberthaw Index, based on a 1914 building
American Appraisal Co. Index (for several cities). 1913 = 100
Associated General Contractors Index. 1913 = 100
Boeckh Index, for several cities. 1926–1929 = 100
Fruin Colnon Index, for St. Louis. 1913 = 100
George A. Fuller Index, for three buildings. 1913 = 100

Turner Index, for eastern cities. 1913 = 100
Handy Public Utility Index. Semiannual. 1911–1914 = 100

Railroad construction cost indexes:

Engineering Section, Bureau of Valuation, Interstate Commerce Commission (annual). 1910–1914 = 100

Public utility construction cost index:

Handy Public Utility Construction Cost, Compiled and published Jan. 1 and July 1 of each year by Whitman, Requardt & Associates and Benjamin L. Smith & Associates.

1. Cost Trends of Building Construction. Semiannual. 1911 to 1914 = 100
2. *Cost Trends of Gas Plant Construction. Semiannual. 1911 = 100*
3. Cost Trends of Electric Light and Power Construction. 1911 = 100

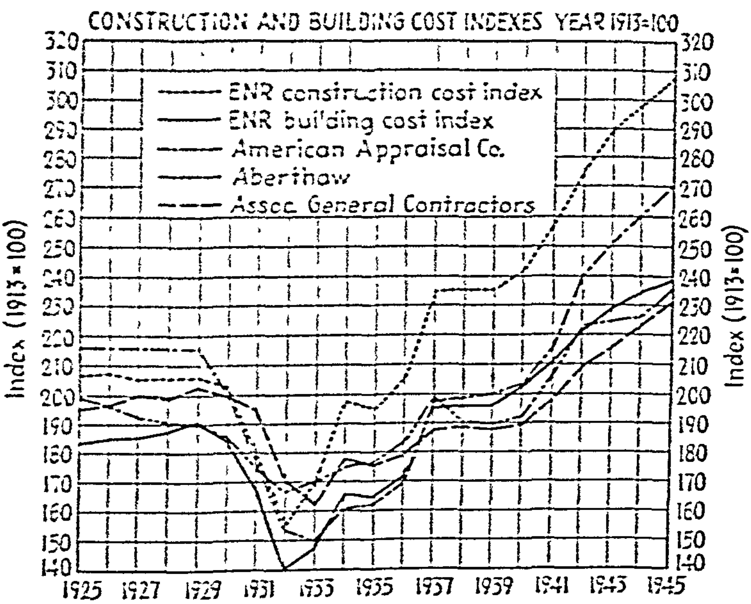

FIG. 20-1.—Construction and building cost indexes, 1913 = 100. (*Data from Engineering News-Record, Apr. 18, 1946.*)

Figures 20-1, 20-2, and 20-3 show some cost indexes expressed in graphical form. Figure 20-4 shows yearly variations in construction wages for skilled and unskilled labor.

In addition to the various cost indexes that are published by various authorities, the estimator should study trends in prices

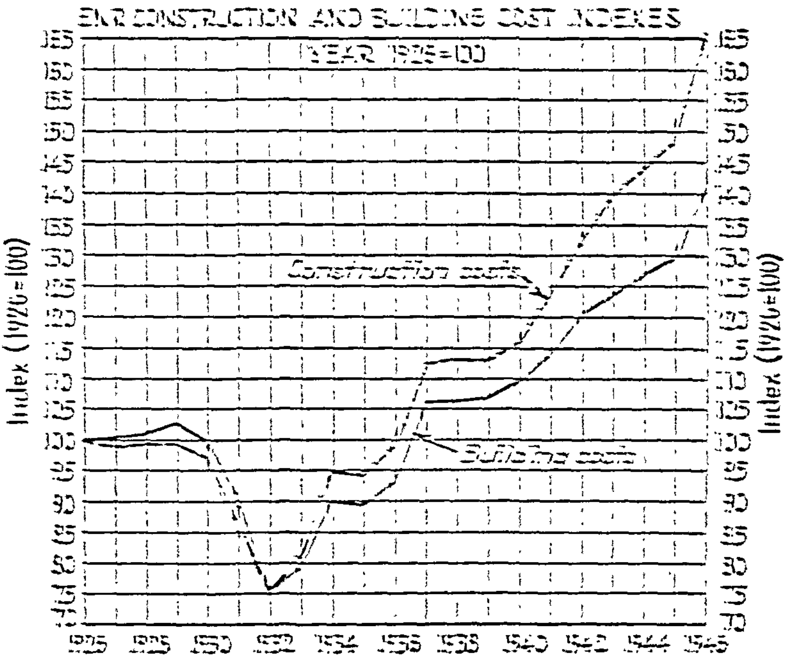

FIG. 21-2.—*Engineering News-Record* construction and building cost indexes, 1926 = 100. (*Data from Engineering News-Record*, Apr. 18, 1946.)

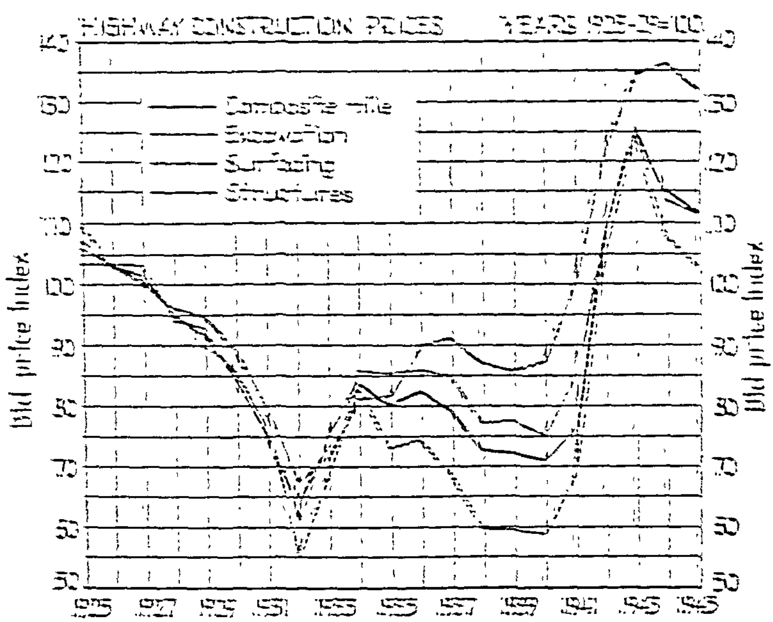

FIG. 21-3.—Highway-construction price indexes, 1925–1929 = 100. (*Data from Engineering News-Record*, Apr. 18, 1946.)

of construction materials and trends in construction wage rates. Much information is given in the *Engineering News-Record* and other publications in regard to price and wage trends. This information is both comprehensive and instructive.

Other information, which may prove useful, is that relating to building permits issued in cities; construction expenditure for different kinds of construction (both public and private) in different sections of the country; and domestic money rates.

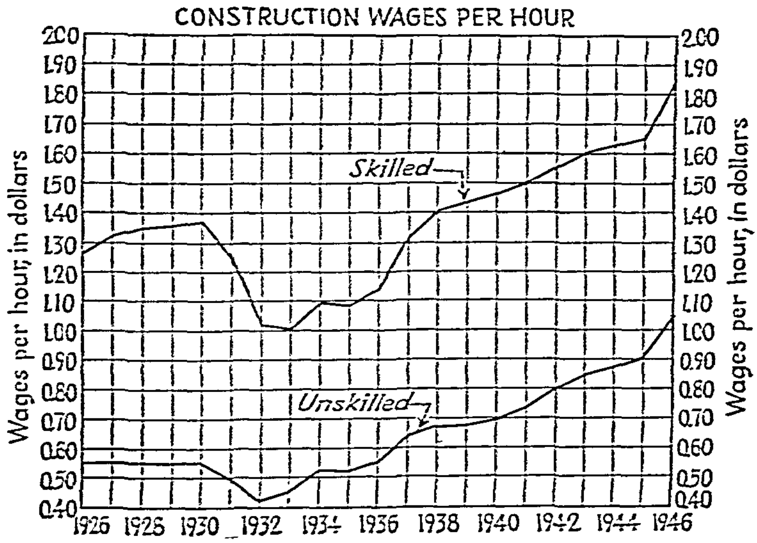

FIG. 20-4.—Construction wages per hour for skilled and unskilled labor. The skilled labor rates are for bricklayers, carpenters, and iron workers. Both skilled and unskilled labor rates are averages from twenty cities. (*Data from Engineering News-Record, Apr.* 18, 1946.)

The estimator should study unit bid prices for different kinds of construction in various parts of the country so that he may obtain information on prices bid by various contractors.

CHAPTER XXI

CONSTRUCTION MANAGEMENT

An experienced contractor once said that there were two important steps in the successful performance of a construction job.

1. The work must be carefully planned and scheduled.
2. The work must be kept up to schedule by means of thorough supervision aided by adequate records of the progress.

A. PLANNING THE WORK

1. Tentative Plan.—As soon as the contract is signed, the contractor must plan on starting the work on the date set and on finishing the work on or before the date set for completion. An experienced contractor does not have to do much planning for a small job because he already knows what to do and when to do it. For a large job, the planning must be more systematically and carefully done. Records must be kept in detail, as the contractor should not rely on his "head" for all the various details.

The first step on planning a large job is to prepare a rough or tentative plan. In this plan, the contractor should list the different parts or kinds of work that are to be done, the approximate time needed for each part, and the approximate dates at which each kind of work should be started and finished.

After these approximate dates have been listed, the contractor must determine in a general way the various kinds and sizes of construction equipment required. He will note what equipment he has available and what equipment he may need to purchase or rent.

Then the classes of labor (various skilled and unskilled) needed may be listed, the approximate date or times that they will be required noted, and the number of each class estimated. The contractor will plan in a general way on how many men of his "permanent" organization he will use on the job and on how many new men he will need to hire. He will also note which men he will use for superintendents and general foremen.

The contractor will note approximately when and where the orders for materials should be placed and about when the deliveries should be made and in what quantities.

Consideration should be given to the subcontractors and their work. Approximate dates of starting and completion of work should be noted in each case.

Some thought at this time should be given to the overhead for the job and to how this is to be cared for.

After the contractor has prepared his tentative or rough plan, he is ready to proceed with the preparation of the detailed plans.

2. Visiting the Site.—Before starting the detailed plans for the work, the contractor and his superintendent should visit the site again. They should preferably be accompanied by the owner or the owner's representative, the architect, or the engineer as the case may be.

The job should be discussed in a general way. Notes should be taken concerning the opinions and suggestions of the owner, architect, engineer, or their representatives. Such notes will be of value if differences of opinion and arguments should develop later.

After going over the site with the owner, architect, or engineer, the contractor and his superintendent or foreman should go over the site again and discuss the construction work in detail. Such things as the location of the office shanty, sheds, tower, and major pieces of equipment may be tentatively decided upon and noted. Sketches should be made when desirable.

Before leaving the locality, the contractor may take additional notes to supplement the information already obtained in previous visits. Additional information may be needed in regard to such items as local ordinances and regulations, permits, banking facilities, light, power, water, sanitation, roads and streets, railway siding, trucking, local material dealers, local labor supply, and boarding and rooming facilities.

3. Planning Plant and Equipment.—After the site has been visited and studied, the plant may be planned. First, the work must be visualized in detail, keeping in mind the conditions at the site, the kinds and amounts of work to be done, the equipment that may be used, and that available.

Then suitable equipment may be selected. The machines should be such that they will work well together and so that the

labor that may need to be imported from another locality. Boarding and rooming places will be needed for imported labor. If local facilities are not sufficient, the contractor may need to provide board and lodging.

Consideration should also be given to construction trends, labor trends, and wages. The amount of construction varies from time to time and in different localities. Likewise, the labor supply and labor wages will vary from time to time and in different localities. In general, when there is a large amount of construction work in any locality, the labor supply will be low, the wages will be high, and the labor efficiency will be low.

Labor wages depend not only upon the amount of work and the labor supply available, but also upon several other items such as union rules and regulations, government regulations, general prosperity of the country or locality, work available in other fields (offices, factories, industries, stores, etc.), and currency inflation. In general, currency inflation will cause an increase in wages, but wages will rarely keep pace with the inflation and will lag behind. The opposite is true when there is a currency deflation. Information concerning labor wages and trends may be found in such publications as the *Engineering News-Record.*

6. Planning Materials.—When planning materials, consideration should be given to such things as prices, price trends, time to buy, amounts to buy, dealers or manufacturers, transportation, deliveries, amounts to be kept on hand, checking, testing, insurance, and follow up.

The correct procedure in buying construction materials is to purchase these materials so that they will arrive at the job in proper order, in the correct amounts, and at the right times. The materials must also conform to all specification requirements.

An expert buyer must be familiar with the markets, prices, factories (producers), shipping rates, time required for transportation of materials from producer to job, tracing of shipments, and the reliability of different producers.

Some producers are very careful to see that their products are of the proper quality and are shipped at the desired times and in the correct amounts. Other producers are not so careful in regard to the uniformity of quality of their products, and they also may be careless in their shipments, shipping either too soon or too late and not always in the correct amounts.

When the market prices are remaining stationary, only the necessary quantities of the materials may be purchased from time to time to keep the work progressing in the most efficient manner. Contracts for the materials may be made a reasonable time in advance. Discounts for prompt payments (like 2 per cent off in 10 days) should always be taken advantage of when the contractor's finances permit.

When the market prices are falling, materials should be purchased only as needed and in as small quantities as possible. Sometimes some risk may be run of delaying the work a short time in order to secure better prices on the materials.

When the market prices are rising, the materials for a job should be purchased as soon as possible, due consideration being given to the contractor's finances. If not purchased outright, the materials should be contracted for in advance so that the contractor will not have to pay higher prices later.

Some consideration must be given to the way in which prices are quoted. Some examples are f.o.b. manufacturing plant, f.o.b. nearest railway siding, delivered at job, carload lots or less than carload lots, crated or uncrated, minimum quantities, extra prices for small quantities, odd sizes, special deliveries, discounts from list prices, discounts for prompt payments, etc.

Much information concerning materials prices and price trends may be obtained from such publications as the *Engineering News-Record.*

Some consideration should be given to the method of transporting the materials from the manufacturer or producer to the job. The materials may be transported by railway, boat, or truck. The expense of transportation, probable time required, including delays, and the reliability of the transportation company should be considered.

When planning on deliveries, some thought must be given to the total amount of each material, the amounts of each material to be kept on the job (such as a few day's supply, a week's supply, or the entire supply), the time or date that the material will be needed, and the rate at which each material will be used. Materials should not arrive at the job too soon or in too large quantities so that other work will be interfered with or that the materials will need much rehandling.

Some thought must also be given in regard to the overhead work required in checking purchases, testing materials, insurance, checking shipments, tracing of shipments during transportation, unloading, storage, watching, etc.

On most jobs, it is advisable to contract for all materials as to price, quality, quantity, delivery, etc., before the work starts on the job. When practical, some allowance should be made for variations in quality, quantity, and delivery because the job conditions and needs may vary after work starts. Sometimes clauses are included regarding unavoidable delays. Other clauses may be included regarding changes in prices.

Materials time schedules should be prepared for nearly all medium- and large-sized jobs. Such a schedule may be prepared in a simple tabular or graphical form. The schedule should show such information as kind of materials, total amounts of each kind, delivery dates for each kind, and amounts of each kind to be delivered on each date. Schedules may also show dates of first delivery and minimum amounts of each kind of material to be kept on hand at the job after the first delivery date and until all the required material is used up. Some schedules may also show prices delivered at the job.

7. Planning Overhead.—Every construction job will require more or less overhead. Before starting work on any particular job, some plan should be provided for handling the necessary overhead work for that job.

In the main office, the overhead work for the particular job may be assigned to certain clerks, draftsman, and stenographers, under the general supervision of one of the executives of the company. They will prepare drawings, keep records, care for correspondence, check job reports, look after materials orders and transportation, trace shipments, check on pay rolls, insurance, social security, care for permits, etc. A reminder or tickler file is often useful. Plans must be made for inspecting and keeping records of the materials to be furnished and the work to be done by the subcontractors.

On the job, advance plans should be made in regard to the superintendent, general foreman, other general employees, records, reports, etc., as may be required for all necessary overhead work at the job. Provision must be made for keeping track of the work of the subcontractors on the job.

8. Planning Subcontracts.—On most jobs, all subcontracts should be let before work starts. The subcontractors will have full information given in their contracts as to the materials they are to furnish, the work they are to do, and other contractural relations they are to fulfill. The subcontractors should also know the approximate dates they are to start and finish their work, and some information should be given in regard to the rate of progress.

A time and work schedule should be prepared for all work to be done by subcontractors. This may be a separate schedule or it may be included with the general job schedule. The time and work schedule for the subcontractors should show the kinds of work to be done, the names of the subcontractors, the dates for starting and finishing the work, and notes regarding the rate of progress and other details.

9. Planning the Management of the Job.—The general planning of the management of a job includes the bringing together and coordinating of all the various plans mentioned in the preceding articles of this chapter. The items considered are tentative or rough plan, visit to site, plant plan, labor plan, materials plan, overhead plan, and subcontract plan.

Many large contractors have planning departments whose duty is to plan the work. This department is usually kept separate from the executive or construction departments because they have found that better results are secured when the "planning" is separated from the "doing."

The work of a planning department may be briefly outlined as follows:

1. Preliminary work plans (before actual work starts on the job).
   a. Work in main office.
   b. Work in job office.
2. Construction work plans (after actual work starts on the job).
   a. Work in main office.
   b. Work in job office.

It is the work of the planning department to prepare all time and work plans for the job in question. The plans are prepared after consultation with company executives and superintendents.

The plans must be flexible so that they can be changed from time to time if necessary.

In addition to preparing the plans, the planning department keeps records as to the progress and costs of the work, suggests changes in plans when advisable, reports all discrepancies between plans and actual work to superiors, may make investigations as to causes of discrepancies between plans and actual work, and may make suggestions relating to improvement of the work, especially in regard to progress and costs.

When properly and carefully done, the work of the planning department is of great service to the contractor in giving him information in regard to the rate of progress of the different kinds of work on the job, in regard to the costs of this work, and in giving him an opportunity to correct errors in planning and execution and to regulate the progress of the work.

10. Time and Work Schedules.—On medium-sized and large jobs, it is advisable to provide time and work schedules for the convenience of the main office, the superintendent, and the foremen. Such a schedule lists the different construction operations, the estimated dates that each operation should start and finish, and the actual dates. Such a schedule, together with progress reports and charts (if the job is a large one), enables the contractor or engineer to note whether the work is progressing as planned, and to observe which items are ahead or behind the schedule.

Certain construction operations and trades should follow each other in regular order and without interference. Confusion, with a resulting loss of efficient work, often occurs when two comparatively large gangs are scheduled to work on the same part of a job at the same time. Two small gangs may frequently work on the job at the same time (such as plumbers and electricians doing rough plumbing and wiring in a residence) without interference. In general, the paint gang should come last (except for priming coat work) on any section of the job.

It is not necessary for any one operation to be wholly completed before another operation is started, but the work should be so planned that the different operations will not interfere with each other. For instance, on concrete-paving work, the excavation gang should be about a half a day or a day in advance of the roller, and the concreting gang should follow about a day behind

One Course Paving Job

TIME AND WORK SCHEDULE

TYPE OF WORK: One-course concrete pavement

LOCATION: Highway 147. SUPT. Conway

No.	Item	Estimated dates		Actual dates	
		Start	Finish	Start	Finish
1	Minor excavation				
2	Rolling subgrade				
3	Forming				
4	Concreting and finishing				
5	Curing				
6	Removing forms				
7	Cleaning up				
8	Finishing shoulders				
9	Completion, schedule time				
10	Completion, contract time				

Garage Building

TIME AND WORK SCHEDULE

TYPE OF BUILDING: Garage

LOCATION: 2463 First St. SUPT. Hanson

No.	Item	Estimated dates		Actual dates	
		Start	Finish	Start	Finish
1	Excavation				
2	Make and erect forms				
3	Bend and place steel				
4	Mix and place concrete				
5	Remove forms				
6	Finish concrete surface				
7	Brick work				
8	Sash, frames, and trim				
9	Glass and glazing				
10	Roofing and flashing				
11	Plumbing				
12	Steam fitting (heating)				
13	Wiring				
14	Cleaning up				
15	Painting				
16	Schedule time of completion				
17	Contract time of completion				

SUBCONTRACTORS JOB SCHEDULE
TYPE OF BLDG.: Steel-frame 7-story office
LOCATION: 211 Grand Ave. SUPT. Fowler

No.	Item	Estimated dates		Actual dates	
		Start	Finish	Start	Finish
101	Elevators				
102	Plumbing, rough				
103	Plumbing, finish				
104	Heating and air conditioning, rough				
105	Heating and air conditioning, finish				
106	Electrical, rough				
107	Electrical, finish				
108	Sheet-metal work				
109	Painting and decorating				
110	Etc.				
111	Schedule time for building				
112	Contract time for building				

B. MANAGING THE JOB

12. Starting the Work.—All necessary preliminary work, such as discussed in the first part of this chapter, should preferably be completed before the actual work on the job is started. That is the work will have been well planned in advance. The plant will have been designed and secured; labor supply will be arranged for; materials' orders will have been given and deliveries decided upon; all necessary permits will have been obtained; subcontracts will have been let (or be ready to let) and subcontractors informed as to their work; and all other preliminary work cared for.

A day or so before the work on the job is to start, the boss (contractor or superintendent) should visit the site again with a foreman and spend as much time as is necessary checking over plans previously made and planning the actual work.

On the day the work is to start, the superintendent should be present with a foreman and a gang of men to assist in placing the construction equipment as it arrives; erect job office, tool shed, and other temporary buildings; see that telephone, light, and water is provided for; and care for supplies of materials as they arrive and need to be stored or piled. One or more copies of the

plans and specifications for the job and the various time and work schedules should be kept on the job at all times.

13. Work in the Main Office.—The superintendent or foreman on the job cannot accomplish much unless the main office does its share of the work. At the main office, some one man should be responsible for each particular job. This man should preferably be an experienced officer of the company. He should keep track of all matters pertaining to this particular job, and should know whether these matters relate to the superintendent, foremen, laborers, subcontractors, material men, owners, or architects. It is expected that he will consult other officials of the firm whenever advisable.

If the job is a large one, a superintendent should be placed in charge of the job, and all correspondence relating to the job should pass through his hands. He should give all orders to foremen and material men and should be kept informed of what is going on even though he does not transact all the business relating to the job. The superintendent may divide his time between the main office and the job.

A full set of plans and specifications and copies of all time and work schedules should be kept in the main office at all times. If the job is a large one, an extra set or two of plans and specifications should be provided so that a set can be loaned to material men or subcontractors from time to time. It is usually advisable to keep the plans and specifications flat in a large shallow drawer. One or more drawers, properly labeled, should be provided for each job. Copies of all letters and memorandums relating to the job should be kept on file.

Separate contracts should have been drawn up with each material dealer and subcontractor, binding them to provide the materials and do the work as desired. Care should be exercised in setting the dates for providing materials and work so that there will be no delays, and the work will be finished on or a little ahead of the date of completion. Schedules for material men and subcontractors should be kept on file, and these men should be checked frequently to see if they are living up to their contracts.

If special detailed drawings are to be provided from time to time by the architect, they should be provided when needed. It is often advisable to write the architect, calling attention to the

drawings or data needed at specified dates and insisting that he provide them on time.

14. Work on the Job.—The office man in charge of the particular job should visit the job occasionally so that he can be informed of what is going on. The boss or superintendent (if he does not spend full time at the job) should visit the job preferably once or twice daily. He should spend enough time on the job with the foremen to see that the work is progressing favorably and that delays are avoided.

When the boss visits the job, it is a good plan for him to go over all parts of the job, and observe everything that is being done by the company workmen and by the subcontractors.

It is a good plan for the superintendent to go over the work in detail each day with the foremen and discuss matters with them. The superintendent should give instruction to the foremen regarding the work, settle details, make suggestions regarding the work, and note things to be taken up with the owner or architect. The superintendent should be careful to avoid giving direct orders to the workmen, as this duty should be left to the foremen.

The superintendent should be on the lookout for improper and inefficient work at all times. He should be careful to observe if the materials on hand are sufficient and if material deliveries are satisfactory. It is advisable for the superintendent (and the foremen as well) to keep a daily notebook record, or diary, concerning the work.

The superintendent should keep the work progressing according to the planned time and work schedule as nearly as possible. He should consult with the main office regarding all changes in the time and work schedule.

The main office will undoubtedly require several daily and weekly reports in regard to the work. The superintendent should see that all required reports are prepared by himself, foreman, timekeepers, and clerks and sent to the main office.

When work is being done by subcontractors, the superintendent should see that they do their work in accordance with the plans and specifications, and also in accordance with the time and work schedules. Discrepancies in materials and workmanship should be reported to the main office. If necessary, work should be

stopped. The superintendent should make arrangements so that the subcontractors can proceed with their work in an efficient manner and without unnecessary interference from (or with) other workmen.

The superintendent should consult the architect or engineer frequently and secure needed instructions in advance concerning all doubtful details of the work. This procedure will avoid tearing down and doing over certain parts of the work at the contractor's expense.

The superintendent should be a good "finisher" as well as a good "starter." He must be careful not to let his energy, persistance, and enthusiasm diminish as the work progresses. He must endeavor at all times to keep the work up to schedule in regard to time, quality, quantity, and costs. Most men can start a piece of work more easily than they can finish it.

15. Reports and Records.—Most large construction companies require that daily and weekly reports be sent from the job to the main office, describing in detail the work that has been done. The daily reports should give information about materials received, used, and on hand; numbers and kinds of laborers and their work; amounts of different kinds of work done; work done by subcontractors; and any other information deemed of value. These reports may be prepared by the superintendent, foremen, timekeepers, or clerks as required, and preferably signed by the superintendent.

In addition to the daily and weekly reports and records, a daily dairy should be kept by the proper official in which all essentials relating to the particular job are noted. Photographs of the work may be taken from time to time and copies included in the dairy.

The main office, by means of the daily reports and records, is enabled to keep in close touch with the job and to take any needed steps in regard to materials and labor. The daily reports should be checked by a competent official to provide against possible dishonesty and errors.

Weekly and monthly summary reports may be prepared as desired by using the information given in the daily reports and records.

16. Progress Reports and Charts.—So that the owner, contractor, architect, or engineer may clearly and easily visualize the

amount of work done, the rate of progress of the job and the cost of the work, progress charts are prepared and kept up to date. A progress chart is a graphical representation of the progress of the work on the job in question. These charts are prepared from the data given in the progress reports and must be kept up to date. A progress chart may be simple or complicated and may show a few or many details, as the case may be. The charts should not be too complicated, or contain too much detail, if they are to be read and understood by the average person.

Some companies prepare their progress charts in blueprint form with the estimated quantities of work and time shown as on the original tracing and the actual progress filled in each week by a colored crayon or full heavy line. When issued weekly, those charts are of value in indicating the progress of the work.

There are a great many kinds of progress charts. Almost every large construction company has its own type of charts. Most charts show progress of work in terms of time rates of different kinds of work. Some charts show comparisons between total estimated and actual costs, and other charts show unit costs. Only a few types of charts will be discussed in this chapter.

On certain jobs requiring large amounts of work of certain kinds and extending over comparatively long times, such as large excavation jobs or large concrete jobs, it is often advisable to prepare a unit-cost chart showing how the actual costs compare with the estimated costs. Figure 21-1 shows such a chart prepared for an excavating job. The horizontal dashed line shows the estimated cost, and the zigzag full line shows the actual costs which were computed at the end of each week and for that particular week. When the full line is *below* the dashed line, the actual costs are *less* than the estimated costs, and the work is being done at a profit greater than that estimated. When the full line is *above* the dashed line, the actual costs are *more* than the estimated costs and the work is being done at a profit less than that estimated, and perhaps at a loss.

An easily understandable form of progress chart is an outline sketch of the structure with the progress made each month (or week) shown by different colors. An example of this form of progress chart would be an elevation of a building or bridge with the progress made each month indicated by different colors.

A popular form of chart for showing the actual weekly progress of the work is one in which the various items of work are listed in the vertical left-hand column, with the allotted times extending horizontally to the right across the remainder of the sheet. Such a chart is easy to read and understand.

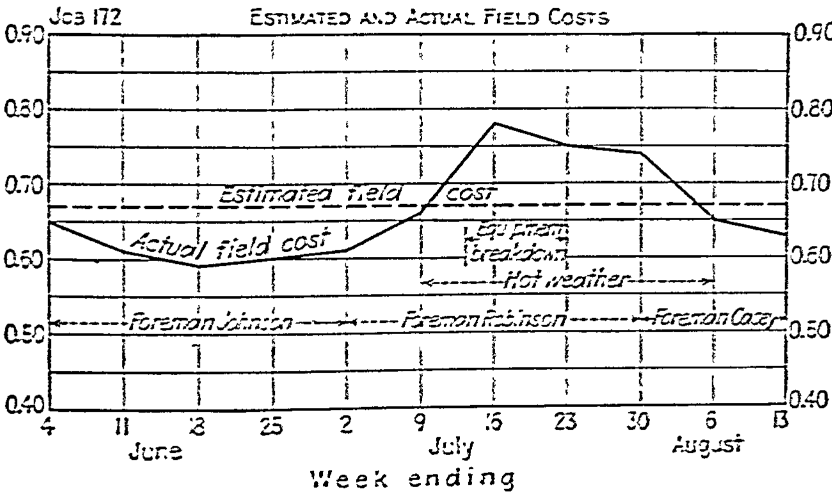

FIG. 21-1.—Estimated and actual unit costs.

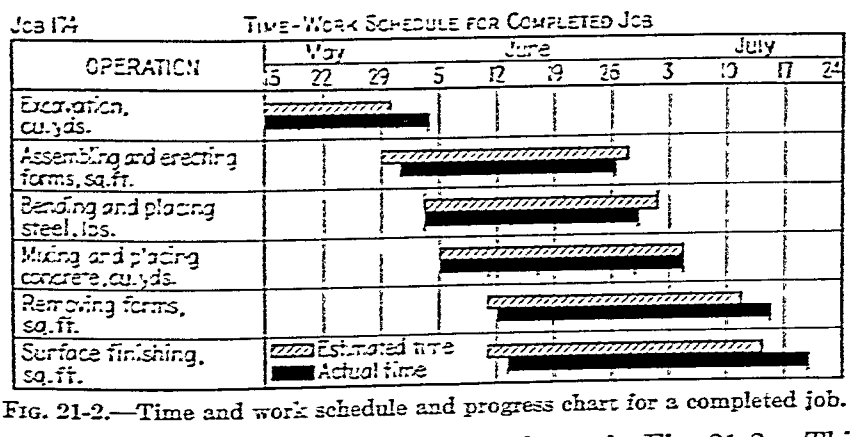

FIG. 21-2.—Time and work schedule and progress chart for a completed job.

An example of this type of chart is shown in Fig. 21-2. This particular chart shows a time-work schedule for a concrete construction job involving excavation, assembling and erecting forms, bending and placing steel reinforcement, mixing and placing concrete, removing forms, and surface finishing. The cross-hatched lines show the estimated time, and the full heavy lines show the actual time required. Each of the horizontal work lines are divided into 5 parts as indicated by the short vertical lines. Each vertical line indicates 20 per cent. Note that this chart is for the completed job. Such a chart may be readily

For an example, the construction of a one-family wood-frame residence will be considered.

When starting work, the first step would be the staking out of the building according to the plans and specifications. Then the tool shed could be erected and the equipment for excavating could be brought to the job.

While the excavating was being done, the equipment for concrete work could be brought to the job and lumber for form work and concrete materials should be delivered.

After the basement walls have been formed and the concrete poured, lumber for framing should be delivered and the carpenter crew organized. The framing should start as soon as the concrete walls are strong enough to carry the loads and permit the removal of forms.

While the rough carpenter work is being completed, the rough work for heating, plumbing, and wiring may be started and completed when the carpenter crew is putting on the roof.

Then the lathing and plastering crews may do their work. At this time, the carpenter crew may do the exterior finish work. The concrete floor in the basement may be poured and finished. Sheet-metal work may be installed as convenient.

After the plastering work is completed, the building should be cleaned. Finished carpenter work may be started as soon as the plaster is dry enough. Finish plumbing and heating work may now be installed. Electrical finish work may be installed except light fixtures and outlet plates, which should wait until after the painting is completed.

At about this time, the yard may be graded and the required concrete walks and drives built.

When the floors are sanded, the painters may start work and work as rapidly as conditions permit. Light fixtures, outlet plates, and other miscellaneous finish work may now be done and the building prepared for delivery to the owner. Needless to state, the premises should be cleaned up before final delivery to the owner.

The contractor on a small job will need to keep complete records in regard to construction equipment, materials, labor, and overhead costs, and also some records in regard to the work done by subcontractors. Although the records should be complete, they need not be kept in as an elaborate and detailed form as for a large construction job.

APPENDIX A

REMINDER LIST

Some estimators use a reminder list, and check off each item after its cost is computed. Separate lists should be prepared for different kinds of jobs, or there should be a list for reinforced concrete buildings, another for a structural-steel building, another for a steel-bridge job, another for a highway job, etc. Such reminder lists are very helpful. However, it is practically impossible to prepare a reminder list that will be absolutely complete. Consequently, an estimator should not depend too much on a reminder list and neglect to study the plans and specifications carefully for little details and notes and inconspicuous clauses.

The following has been abstracted with permission from the *Engineering News-Record*, May 6, 1937:

ELEMENTS OF BUILDING COSTS

The cost of building construction is the aggregate of scores of items, both large and small. Many of these details are liable to be overlooked by the estimator or engineer in figuring building costs. The following tabulation is offered as a check list for the benefit of the building estimator and contractor. It has been compiled from similar lists used by several prominent building construction firms, and is more complete than any of the individual lists, for it contains all of the items listed in the various sources.

Check List of Building Costs

1. Foundations and Fireproofing:

   Caissons, piling, shoring, and bracing.
   Tests, borings, general excavation, deep basement, footings.
   Concrete footings, slabs, beams, girders, walls.
   Drop panels, columns, column caps, stairs.
   Tile and joist slab concrete, tile, dome.
   Metal tile, sacket board, metal lath.
   Backfill, tile drains, floor tests.

2. Forms:

   Slabs, drop panels, beams, spandrels, girders.
   Columns, walls, shores, column clamps.
   Bulkheads, special construction, footings, stairs.

3. **Reinforcing Steel:**

Setting, hauling, bending.
Wire mesh, bar spacers, royalties.

4. **Structural Steel:**

Tie rods, rivets, bolts, cast-iron separators.
Steel stack, stack lining, set steel stack, grillages.
Unload at storage, yard rental, reloading.
Extra freight, hauling, demurrage.
Remove rust, paint steel.
Labor setting grillage, cast-iron bases, riveting, bolting.
Welding.
Engineering and designing.
Shop details, inspection.

5. **Ornamental and Miscellaneous Iron:**

Stairs, safety treads, railings.
Wheel guards, column guards.
Flagpoles, shop fronts, vault lights.
Fire escapes, permits, anchors, platforms.
Steel lintels, access doors and frames.
Bronze, directory board.
Door hangers, door-opening devices.
Mail chutes, garbage chute, floor thimbles, backboard.
Linen chute, dust chute, box, angles.
Small tools, erection bolts, burning equipment.
Power, coal, oil, maintenance of equipment.

6. **Masonry and Cut Stone:**

Wrecking, old buildings, old foundations, walls, floors, sidewalks.
Grout grillage, bases, columns, spandrels, terra cotta, machinery foundations.
Shoring banks, adjoining buildings, trenches, sheet piling, lagging.
Pumping, bailing.
Granite pier caps and foundations, rubble-stone work.
Waterproofing, fabric, compound; dampproofing, slate or tar course.
Drain tile, flue lining, wall coping, anchors, raggle blocks.
Terra-cotta tile, ornamental terra cotta, glass block.
Gypsum block, column covering, furring, partition tile.
Common brick, hollow brick, mortar, scaffold.
Face brick, shape brick, mortar, mortar color, scaffold, enamel brick.
Fire brick, radial brick stack, brick underpinning.
Cleaning, pointing, sandblasting, steam cleaning.
Setting miscellaneous iron.
Small tools, power, coal, oil, maintenance and repairs to equipment.
Hoisting masonry, materials; carving.
Terra cotta, setting, anchors, scaffold, mortar, hoist, models.

Cut stone, setting, anchors, lewising, limestone, sandstone, models.
Granite, setting, anchors, lewising, monoliths, polishing, carving, models.

7. **Cement Fills and Finishes:**

Dry cinders under floors on ground, sidewalks, driveways, roof fill.
Rough concrete, floors, sidewalk, driveway on ground, curb, gutters.
Finish cement, floors, sidewalk, roof finish, hardener base, treads.
Cement sills, water tables, coping wash finish, bushhammer work.
Cinder concrete, sleeper fill, roof fill, concrete fill over steel.
Concrete fill under wood, marble, tile, composition, floors; roof.
Reinforcing steel, wire mesh in floors, sidewalks, driveways.
Bonding coat, preparation of rough floors for finish.
Cement gun work.
Floors and pavements, brick, wood block, asphalt, mastic, macadam.

8. **Mill and Cabinet Work:**

Frames and sash, trim, cabinet finish, revolving doors, screens.
Rough work on store fronts, bulkheads, and entrance doors.
Bucks, rough partitions, steel partitions, rough carpentry.
Grounds, rough window sills, wood wall and ceiling furring strips.
Floor sleepers, carpet strips, sleeper clips.
Under floors, roof sheathing, building paper, deadening felt.
Finish floors, maple, oak, pine, laying, scraping, sanding, parquetry.
Set outside wood window frames, fit sash, and apply hardware.
Rough work around skylights, ceiling lights, scuttle, cornice, gutters.
Timbers, joist, posts, floor, cast-iron post caps and shoes; joist hangers.
Flagpoles, fittings, rough hardware, sash weights, chain, pulleys.
Window-cleaning devices.
Weather strips.
Caulking.
Set and trim doors, windows, base, picture mold, chair rail, mold.
Stair and hand rail, wood stairs.
Closet shelving, hooks.
Telephone booths, medicine cabinets, wardrobes, counters, blinds.
Wood carving, compo ornaments.

9. **Finish Hardware:**

Kick plates, coat hooks, bead screws, strikes, window hardware.
Door checks, butts, hinges, lock sets, escutcheons, pulls, thumb bolts.

10. **Plastering and Lathing:**

Furring, corner beads, cement base, stucco, solid partitions.
Cornice, molding, models.

11. **Glass and Glazing:**

Plate, prismatic sheet, art, wire, mirrors, corner bars, vault glass.

12. Metal Windows and Doors:

 Underwriter hardware, glass and glazing, set frames, auto hardware.
 Metal jambs, trim, baked enamel finish, Kalamein, art metal.
 Elevator enclosures and fronts, special doors, shutters, operators.

13. Roofing and Sheet Metal:

 Composition, slate, tile, guarantee, insulation.
 Flashings, cornice, skylights, ventilators, louvres, tin fire doors.
 Duct work, gutters, downspouts.

14. Plumbing and Sewerage:

 Gas fitting, meters, filters, tanks, pumps, gas lines.
 Fixtures, medicine cabinets, shower doors, curtains.

15. Heating, Ventilation, and Power Plant:

 Boilers, stokers, temperature regulators, pipe covering.
 Fans, ducts, high-pressure piping, engines, generators.
 Switchboard, oil tanks, fire-brick linings.

16. Electric Wiring and Fixtures:

 Telephone, telautograph, carriage call, clock system.
 Power wiring, gas and electric fixtures, lamps.
 Electric-sign wiring, panel boxes.

17. Elevators:

 Sidewalk lift, dumb-waiters, escalators.
 Cabs, signals, interlocks.

18. Sprinkler System:

 Tank, supply pipe, sprinkler heads, pumps.

19. Refrigeration and Air Conditioning:

 Machines, pumps, tanks, insulation, refrigerators.
 Suspended ceilings, ducts, machine foundations, meters.
 Mesh grilles, fans, filters, thermometers, awnings.

20. Pneumatic Service:

 Pneumatic tubes, compressed-air system.

21. Vacuum-cleaning System:

 Piping, power, receiver, sweepers.

22. Marble, Tile, and Terrazzo:

 Slate, carrara, glass, toilet hardware.
 Ceramic, rubber, cork, scagliola, asbestolith.
 Interior stonework, moldings, models, carving.

23. **Vaults and Vault Doors:**

Steel-vault lining, vault fixtures, safes.

24. **Furniture and Fixtures:**

Window shades, venetian blinds, radiator enclosures.
Kitchen, bar, laundry fixtures, mirror doors.
Carpets, linoleum, unit refrigerators.

25. **Painting and Decorating:**

Painting, paper hanging, floor finish.
Special decorations, murals.

26. **General and Administration:**

Permits, water, streets, park, harbor, special.
Survey, blueprints, photos, batter boards.
Fire, glass, tornado insurance.
Liability insurance—employers, public, compensation.
Contingent insurance, social security, state and federal taxes.
Temporary office, telephones, stationery, and supplies.
Traveling expenses.
Sidewalk protection, fences, sheds, runways, stairs, ladders.
Sidewalk bridge, watchman and signal lights.
Temporary light and heat—office, general, sidewalk, caisson.
Repair damage to adjacent property, streets, move poles, hydrants, sewers.
Clean out building, remove rubbish; wash windows and floors.
Plant and equipment, concrete- and brick-handling plants.
Temporary roadways, ramps, storage yards.
Tool account, material and labor furnished subcontractors.
Protect work during and after erection, adjacent property.
Temporary partitions, canvas.
Organization, superintendents, material clerks, timekeepers.

A.G.C. SCHEDULE OF AVERAGE OWNERSHIP EXPENSE (ABBREVIATED).—(*Continued*)

Equipment	Average annual expense, per cent of capital investment without field repairs				Average use, months per year	Expense per working month, per cent	Application to selected prices	
	Depreciation	Overhauling, major repairs, painting	Interest, taxes, storage, insurance	Ownership, total expense			Price	Expense per working month
Buckets (*Contd.*)								
Clamshell digging, Std. 1 cu. yd	25	18	11	54	6	9.0	$ 900	$ 80
Orange-peel, std., 1 cu. yd.	20	20	11	51	6	8.5	1,200	100
Dragline								
Slack-line cableway, 1 cu. yd	25	15	11	51	6	8.5	675	55
Scraper, tower-excavator, 2 cu. yd.	20	15	11	46	6	7.7	975	75
Concrete, bottom-dump, 2 cu. yd.	20	15	11	46	6	7.7	425	35
Cart, concrete								
Steel, stl. wheel, 6 cu. ft.	33	20	11	64	7	9.1	32	3
Steel, pneu. tire, 6 cu. ft.	33	25	11	69	7	9.9	55	5
Cement-gun Machines								
N-1, with nozzle and 50-ft. hose	25	15	11	51	8	6.4	1,550	100
Compressor								
Motor truck unit, gas, 160 cu. ft	20	15	11	46	6	7.7	4,400	339
Portable, gas, 160 cu. ft.	25	15	11	51	6	8.5	3,050	260
Concrete spouting plant complete, incl. bucket, sheaves, auxiliary chute from mixer, and 32-ft. C.B. chute								
Gin-pole type, 75-ft. mast	25	12	11	48	8	6.0	1,050	65
Cage-type, steel, 90-ft. mast	25	12	11	48	8	6.0	1,800	110
Conveyor, elevating belt								
Portable, with power, 24 in., 30 ft.	25	20	11	56	6	9.3	1,100	100
Cranes (see also derrick, (Hoist)								
Motor truck, 5 tons	25	15	11	51	8	6.4	7,500	480
Crawler, diesel, 25 tons	13	10	11	34	7	4.9	17,600	860
Crawler, gas, 10 tons	20	10	11	41	8	5.1	9,200	470
Crawler, gas, 25 tons	13	10	11	34	7	4.9	16,000	785

A.G.C. Schedule of Average Ownership Expense (Abbreviated).—(Continued)

Equipment	Average annual expense, per cent of capital investment without field repairs: Depreciation	Overhauling, major repairs, painting	Interest, taxes, storage, insurance	Ownership, total expense	Average use, months per year	Expense per working month, per cent	Application to selected prices: Price	Expense per working month
Excavator, cable type (Contd.)								
Power drag scrapers, with power 1 cu. yd., 300-ft. span	20	15	11	46	6	7.7	$ 3,300	$ 255
Engines, complete, not mounted								
Diesel, 100-hp.	12	12	11	35	7	5.0	3,500	175
Gas, 10-hp.	20	15	11	46	7	6.6	260	17
Gas, 100-hp.	12	12	11	35	7	5.0	1,800	90
Finishing machines								
Conc. highway, std., gas, 21 to 24 ft.	25	15	11	51	6	8.5	3,550	300
Float bridge, steel, road, 24-ft.	20	10	11	41	6	6.9	250	17
Forms, steel, 1,000-ft. length, with fastenings								
Curb only, 6 in. high	25	20	11	56	6	9.3	600	55
Curb and gutter	25	20	11	56	6	9.3	2,250	210
Integral curb	25	20	11	56	6	9.3	1,800	165
Road, load bearing, 6 by 6 in.	25	20	11	56	6	9.3	1,000	95
Grader (see also Scraper)								
Motor grader, gas (dual-drive)	20	15	11	46	8	5.7	4,300	245
Blade (hand-control), 10-ft.	25	20	11	56	8	7.0	1,450	100
Bulldozer attachment for 50-hp. tractor	25	20	11	56	8	7.0	1,200	95
Form (subgrade planer), 10 ft.	25	20	11	56	6	9.3	435	40
Hoisting unit, no boom slew								
One-drum, gas, 25-hp.	17	10	11	38	8	4.7	1,250	60
Two-drum, electric, 40-hp.	13	10	11	34	8	4.2	2,320	95
Two-drum, gas, 40-hp.	17	10	11	38	8	4.7	2,150	100
Two-drum, steam, 40-hp.	13	10	11	34	8	4.2	2,200	90
Three-drum, gas, 60-hp.	17	10	11	34	8	4.7	3,400	160
Jacks								
Hydraulic, 17-in. rise, 60-ton	13	15	11	39	5	7.8	390	30

A.G.C. SCHEDULE OF AVERAGE OWNERSHIP EXPENSE (ABBREVIATED).—*(Continued)*

Equipment	Average annual expense, per cent of capital investment without field repairs				Average use, months per year	Expense per working month, per cent	Application to selected prices	
	Depreciation	Overhauling, major repairs, painting	Interest, taxes, storage, insurance	Ownership, total expense			Price	Expense per working month
Pipe								
Galv., with conts., 2 in., 1,000 ft.	25	5	11	41	6	6.8	$ 219	$ 15
Black, with conts., 2 in., 1,000 ft.	25	5	11	41	6	6.8	177	12
Pit and quarry plants (portable)								
Crushing, screening and loading single-crusher, small-capacity	25	15	11	51	6	8.5	3,500	300
Heavy-duty, single-crusher, large-capacity	17	12	11	40	6	6.7	12,000	805
Plow, furrow, 250 lb.	33	15	11	59	7	8.4	55	4
Pneumatic tools (see also Drill, vibrator)								
Clay-digger, 40 lb.	33	10	11	54	6	9.0	145	13
Drill, jackhammer, medium	33	10	11	54	6	9.0	190	17
Pavement-breaker, 65 lb.	33	10	11	54	6	9.0	185	17
Pump, sump	33	10	11	54	6	9.0	165	15
Riveter, 1-in. rivet, 25 lb.	33	10	11	54	6	9.0	140	13
Pumping unit								
Centrifugal, portable, gas, 4-in.	20	18	11	49	6	8.2	650	55
Diaphragm, portable, gas, 4-in.	20	20	11	51	6	8.5	275	25
Plunger, portable, gas, 4-in.	20	20	11	51	6	8.5	500	40
Piston, portable, gas, 80 g.p.m.	20	20	11	51	6	8.5	1,250	105
Pump, concrete								
Single-skids, gas, 25–33 cu. yd. per hour	25	15	11	51	6	8.5	5,450	465
(with remixer)	25	15	11	51	6	8.5	7,200	610
Roller								
Hand, steel, 500-lb.	20	10	11	41	6	6.8	60	4
Tandem, gas, 10-ton	14	12	11	37	8	4.6	4,500	205
Three-wheel, gas, 10-ton	14	12	11	37	8	4.6	4,100	190
Tamping (sheepsfoot), 8 ft. wide	33	20	11	64	8	8.0	1,250	100

SAMPLE EQUIPMENT RENTAL RATES.—(*Continued*)

Item	Per month	Per week	Per day
Buckets:			
Clamshell, $\frac{3}{8}$ cu yd	$ 67	$ 22	$ 5.00
Clamshell, $\frac{3}{4}$ cu. yd	90	30	7.50
Clamshell, $1\frac{1}{2}$ cu. yd	140	46	11.50
Concrete bottom-dump, 1 cu yd	35	$11\frac{1}{2}$	3.00
Concrete bottom-dump, 2 cu. yd	50	$16\frac{3}{4}$	4.25
Dragline, 1 cu. yd	85	28	7.00
Dragline, $1\frac{1}{2}$ cu. yd	105	35	8.75
Dragline, 2 cu yd	125	42	10.50
Orange-peel, $1\frac{1}{4}$ cu yd	175	58	14.50
Bulldozers—see Tractors			
Concrete carts:			
6 cu. ft., rubber-tired	12	4	
9–11 cu. ft., rubber-tired	15	5	
Cranes (capacity at ft. radius):			
Crawler gasoline, 4.75–7.375 ton, 12 ft	450	150	38.00
Crawler gasoline, 14.5–19.5 ton, 12 ft	675	225	56.00
Crawler gasoline, $18\frac{1}{2}$–26 ton, 20 ft	1,400	467	117.00
Crawler diesel, $14\frac{1}{2}$–$19\frac{1}{2}$ ton, 12 ft	800	267	62.00
Crawler diesel, $18\frac{1}{2}$–26 ton, 20 ft	1,700	567	142.00
Crawler diesel, $14\frac{1}{2}$–20 ton, 45 ft	2,725	908	227.00
Crawler steam, $18\frac{1}{2}$–$24\frac{1}{2}$ ton, 12 ft	725	242	60.00
Locomotive gas, 27–32 ton, 12 ft	1,300	430	108.00
Locomotive steam, 27–32 ton, 12 ft	1,180	393	98.00
Truck-mounted gas, 7–9 ton, 10 ft. (per hour $5.50)	700	230	58.25
Truck-mounted gas, 12–$14\frac{1}{2}$ ton, 10 ft. (per hour $6.00)	925	300	77.00
Crushers (without accessories or power):			
Openings 9 × 16 in.	85	28	7.00
Openings 10 × 30 in.	190	63	16.00
Openings 12 × 36 in.	265	88	22.00
Derricks:			
Stiffleg, wood, $3\frac{1}{2}$–$4\frac{1}{2}$ ton	100	33	8.50
Stiffleg, steel, 4–6 ton, 50- to 80-ft. boom	215	72	18.00
Stiffleg, steel, 13–17 ton, 100-ft. boom	390	130	33.00
Stiffleg, steel, 32–42 ton, 70- to 100-ft. boom	555	185	46.00
Guy, 13–17 ton, 70- to 110-ft. boom	245	82	20.00
Guy, 35–45 ton, 100- to 120-ft. boom	450	150	37.00
Engines:			
Gasoline with clutch, 22–30 hp	50	17	4.50
Gasoline with clutch, 55–70 hp	90	30	7.50
Diesel with clutch, 22–30 hp	75	25	6.50
Diesel with clutch, 55–70 hp	135	45	11.00
Diesel with clutch, 90–115 hp	245	82	20.00
Fine graders, 11- to 16-ft. width (self-powered)	650	$216\frac{3}{4}$	70.75
Finishing machines:			
Concrete-floor, powered	60	20	5.00
Road finishers, 12–18 ft. roadway	447	149	37.25
Road finishers, 24–30 ft. roadway	495	165	41.25
Bituminous machines	750	250	63.00
Graders:			
Single-drive, 8,600–14,000 lb., gasoline	275	92	23.00
Tandem-drive, 19,000–21,000 lb., gasoline	470	156	39.00
Tandem-drive, 18,500–21,500 lb., diesel	525	173	42.00
Towed-power operated, 9–11 ft	190	63	15.75

SAMPLE EQUIPMENT RENTAL RATES.—(*Continued*)

Item	Per month	Per week	Per day
Surveying instruments:			
Levels	$ 20	$ 8	$ 5.00
Transits	25	9	5.00
Tractor, crawler, and attachments:			
33–44 hp., gasoline	265	88	22.00
66–85 hp., gasoline	425	142	35.00
46–52 hp., diesel	410	137	34.00
72–89 hp., diesel	645	215	54.00
89–135 hp., diesel	775	258	65.00
Winch, any size, double drum	75	25	6.50
Bulldozer, 66–89 hp., tractor	120	40	10.00
Angledozer, 66–89 hp., tractor	148	49	12.00
Tractors, wheeled:			
4-wheel, rubber-tired, diesel, 93–103 hp	530	175	45.00
4-wheel, rubber-tired, diesel, 140–160 hp	855	285	70.00
2-wheel, rubber-tired, diesel, 115–160 hp	780	260	65.00
2-wheel, rubber-tired, diesel, 195–210 hp	1,385	461	115.00
Scrapers and wagons (heaped measure):			
Scraper, 7–10 cu. yd	250	85	21.00
Scraper, 17–22 cu. yd	575	190	48.00
Scraper, 29–37 cu. yd	1,025	340	85.00
Crawler wagons, bottom dump, 9½–12½ cu. yd	240	80	20.00
Crawler wagons, bottom dump, 14½–20½ cu. yd	370	123	31.00
Vibrators, gasoline, flexible shaft:			
Up to 1½ hp., 28-ft. shafting	35	11¾	3.00
3½–4½ hp., 46-ft. shafting	60	20	5.00
Welding machines, wheels or skids:			
Gasoline-engine driven, up to 250 amp.	74	25	6.00
Gasoline-engine driven, 350 to 500 amp.	114	38	9.50
60-cycle, motor driven, up to 250 amp	35	12	3.00
60-cycle, motor driven, 350 to 500 amp	56	19	4.50

CONSTRUCTION EQUIPMENT.—(*Continued*)

Item	Years	Item	Years
Cars:		Cutting and welding outfits, portable	4
Flat, wood	10		
Hand	10	Davits	15
Hopper	10	*Derricks:*	
Scale	10	Boat	10
Skip hoist	10	Circle swing, hand	8
Tank	20	Crab, hand	16
Carts, concrete	3	Crab, power	10
Carts, tool, steel	4	Guy, steel	12
Cement gun machines	4	Guy, wood	8
Chains:		Stiffleg, steel	12
Hawsers and lines	6	Stiffleg, wood	8
Power, transmission	5	Diggers, clay, pneumatic	3
Channelers, rock	6	Draglines:	
Chipping and calking tools, pneumatic		Electric:	
	3	½ and ¾ cu. yd	6
Chutes, concrete, gravity	2	1, 1¼, 1½ cu. yd	8
Clamps, column form	5	2 cu. yd. and over	10
Cleaning machines for exterior of		Gasoline:	
building, steam or sand	15	½, ¾ cu. yd	5
Compressors:		1, 1¼, 1½ cu. yd	9
Belt-driven	10	2 cu. yd. and over	12
Electric, portable	8	Steam:	
Gasoline, portable	6	½ and ¾ cu. yd	6
Motor-truck unit	5	1, 1¼, and 1½ cu. yd	10
Steam, portable	6	2 cu. yd. and over	12
Concrete machines, pneumatic	5	Dredges:	
Concrete mixers:		Clamshell	16
Electric	5	Dipper	8
Gasoline, 3½S, 5S, 7S	3	Hydraulic	20
Gasoline, 10S, 14S	4	Pipe	10
Gasoline, 21S, 28S	5	Drill boats	12
Paving, gas	8	Drill points, well	5
Paving, steam	8	Drills:	
Steam	8	Air drifter	3
Truck-mounted	5	Electric or pneumatic, hand, for	
Controllers, motor	12	wood or metal	5
Conveyors:		Hand, electric	3
Belt, elevating, portable	3	Rock, electric	3
Belt, elevating, stationary	6	Jackhammer	3
Bucket	6	Steam	5
Cable, drag	6	Traction, well	7
Cable, monorail	15	Tripod	7
Chain, portable	6	Tunnel carriage	5
Portable	5	Well	10
Scraper	6	Drums for oil, steel	10
Cranes:			
Bridge and cantilever	20	Elevators:	
Crawler, electric:		Bucket, stationary	6
2½ to 5 tons	5	Cage (steel tower)	5
10 to 15 tons	7	Engines:	
20 tons and over	9	Blowing	12
Crawler, gas:		Fire	7
2½ to 5 tons	5	Gas	10
10 to 15 tons	9	Marine	20
20 tons and over	12	Oil	20
Gas locomotive	7	Plumbing	14
Crawler, steam:		Steam	11
2½ to 5 tons	6	Excavators:	
10 to 15 tons	10	Trench, gasoline:	
20 tons and over	12	7-ft. depth	6
Steam locomotive	10	12-ft. depth	6
Dock or wharf, traveling	20	18-ft. depth	8
Dragline	10	Trench, steam:	
Universal, gas, 2½ to 5 ton,		7-ft. depth	8
mounted on 10-ton truck	6	12-ft. depth	8
Craneways:		18-ft. depth	10
Steel	15	Trench, vertical boom	5
Wood	10	Wheel or ladder type	5
Crushers, rock:		Extinguishers, fire	3
Portable	8		
Stationary	10	Fans, exhaust	15
Cutters:		Finishing machines	4
Bar, power	5	Floats, bridge, steel	5
Corrugated iron, hand	10	Forges, gas- or oil-burning	10

CONSTRUCTION EQUIPMENT.—(*Continued*)

Item	Years	Item	Years
Pumping units:		Spreaders, stone:	
Gas:		Hopper wagon	5
Centrifugal or diaphragm	6	Steel box	5
Highway contractor's pump	4	Steamers, paddle wheel	20
Piston	5	Switches:	
Steam, centrifugal	10	Portable	4
Pumps:		Stationary	5
Air lift	10		
Centrifugal, Humdinger, or Impulse	6	Tampers, backfill, pneumatic	3
Hydraulic	15	Tamping machines	10
Oil	10	Tanks:	
Steam piston unit	6	Gasoline-storage	6
Testing for pipe lines	15	Relay	6
Punches, hydraulic	20	Water- or air-storage, steel	10
Punches for steel, power	15	Water-storage, wood	14
		Tarpaulins and tents	3
Racks, storage, for pipe and steel:		Threading and cutting machines, pipe	10
Steel	20	Ties:	
Wood	15	Steel	12
Rails, steel	10	Wood	6
Razing equipment, for buildings	8	Tongs, chain	4
Reamers, electric or pneumatic	3	Towers:	
Rollers:		Cableway:	
Concrete finishing, steel	10	Steel	6
Road, gas or steam	10	Wood	3
Rolls, ridge	5	Wood with steel boom and counter weights	5
Rowboats	6	Tracks, industrial, portable	6
Sand-blast outfits	10	Tractors:	
Sawmills, portable	10	Electric:	
Saws:		3-ton	3
Band, cutoff and rip, power	10	5-ton	5
Hand, electric, and pneumatic	3	10-ton	6
Saws and woodworkers:		20-ton	8
Steel frame	10	Gas or steam:	
Wood frame	5	3-ton	4
Scales, large, track, and wagon	20	5-ton	6
Scarifiers:		10-ton	8
Attachments	4	20-ton	10
Blocks, steerable	5	Trailers:	
Drag, all-steel	4	Dump, steel or wood	10
Grader type	4	Platform, wood	4
Scows, including dump	25	Drop platform, heavy-duty	5
Scrapers:		Transformers, car	10
Blade, carryall	6	Trenching machines (see Excavators)	
Fresno or Morman	2	Trucks, auto, general purpose or dump:	
Rotary	4	½ to ⅔ cu. yd	3
Slip	2	1 to 1⅔ cu. yd	5
Wheel	5	2 cu. yd. and over	8
Screens and bunkers, for gravel pits	5	Tugs, screw-propelled, steam or gas	25
Screens, revolving	6	Turntables, industrial railway	4
Sharpeners, drill	8	Vises	5
Shears, for steel, hand	10		
Shores, adjustable	4	Wagons:	
Shovel attachments, for cranes	6	Dump, steel or wood	6
Shovels:		Farm, heavy or light	10
Electric or gasoline, crawler or wheel:		Road oilers, tank, steel	10
½ and ¾, cu. yd	5	Tank or sprinkler:	
1, 1¼, and 1½ cu. yd	6	Steel	10
2 cu. yd. and over	8	Wood	8
Steam, crawler or wheel:		Washers, gravel	3
½ and ¾ cu. yd	7	Welding outfits, acetylene or electric	10
1, 1¼, and 1½ cu. yd	8	Wheelbarrows	2
2 cu. yd. and over	10	Winches, electric and pneumatic	10
Railroad, steam	10	Wire and cables:	
Tunnel	4	Electric	6
Spouting plants, complete, concrete	4	Flexible, steel-armored	8
Spraying equipment, paint	12		

APPENDIX E

COMPENSATION INSURANCE RATES FOR CONSTRUCTION

The cost of compensation insurance varies greatly between different classes of work and also between different states. The rates are based upon experience and data collected over a period of years, and are changed from time to time. The base rates are subject to adjustment, either up or down, depending upon whether the individual contractor's experience rating is bad or good.

Careful pay-roll classification may afford an appreciable saving in insurance costs.

When preparing estimates, the estimator should always consult the insurance companies to ascertain the rates which are in effect at the time and in the locality in which the work is to be done, and also which are in effect for the particular contractor and his experience rating.

The following table of base rates for important construction operations gives the rates in effect on Apr. 1, 1946, and shows the variation in these base rates between a few states and between different kinds of work. The data in this table was abstracted, with permission, from the *Engineering News-Record* of Apr. 18, 1946.

The data given in this appendix are for illustrative purposes only and should not be used when preparing actual cost estimates.

BASE RATES ON COMPENSATION INSURANCE FOR CONSTRUCTION, APR. 1, 1946
(Data Compiled by Herbert L. Jamison & Co., Insurance Advisers and Auditors, New York)
(Base rates in effect Apr. 1, 1946, subject to increase or decrease according to experience ratings)

Classification of work*	Ala.	Calif.	Ill.	N.Y.	Wis.
1. Carpentry, private residences	1.37	5.06	2.95	6.31	3.73
2. Carpentry, dwellings 3 *stories or less*	1.37	5.06	2.95	6.31	3.73
3. Carpentry, interior trim	0.81	5.06	1.16	6.31	3.73
4. Carpentry, general	1.98	5.06	4.19	6.31	3.73
5. Concrete- and cement-walk laying†	1.01	1.87	1.80	3.78	2.17
6 Concrete work, general†	2.03	4.50	3.21	6.05	3.31
7. Concrete work, dwellings 3 stories or less†	1.06	4.50	1.90	6.05	2.83
8. Electric wiring	1.00	2.45	1.32	2.69	1.96
9. Excavation, earth‡	1.68	3.19	2.59	5.64	3.86
10. Excavation, rock§	2.87	8.36	4.59	11.31	7.51
11. Glazing	2.32	5.39	3.56	10.50	7.49
12. Lathing	1.10	4.60	1.50	2.95	3.23
13. Masonry	1.06	2.99	2.20	7.80	2.83
14. Painting**	1.95	4.80	2.33	7.39	2.74
15. Plastering	1.29	4.60	1.98	6.12	2.39
16. Plumbing	0.78	1.84	1.26	3.25	1.59
17. Roofing	3.58	9.24	6.86	18.03	10.73
18. Sheet-metal erection	1.73	2.99	2.27	5.60	3.47
19. Steel erection, general	5.86	8.68	8.55	16.35	9.77
20. Steel erection, structural	9.50	16.04	8.55	28.17	13.57
21. Steel erection, interior ornamental	1.59	3.57	2.51	4.59	3.92
22. Steel erection, dwellings 3 stories or less	3.74	16.04	6.37	12.46	6.75
23. Tile laying	0.72	1.40	1.10	4.75	1.54
24. Watchmen and timekeepers¶	1.61	‖	2.65	8.38	4.45
25. Waterproofing:					
Application by brush	1.95	4.46	2.33	7.39	2.74
Application by trowel, interior	1.29	4.46	1.98	6.12	2.39
Application by trowel, exterior	1.06	4.46	2.20	7.80	2.83
Application by pressure gun	2.03	4.46	3.21	6.05	3.31
26. Wrecking	9.25	21.22	13.32	††	27.79

* Special rates for government projects.
† Includes construction of forms.
‡ Includes blasting but not caisson or cofferdam work.
§ Special rates for occupational disease coverage.
‖ Assign operation to principal classification.
¶ Not available if general contractor is conducting operations at job.
** Painting of bridges and steel structures rated as erection.
†† Wrecking of structures based on cubic content.

DIAGRAMS

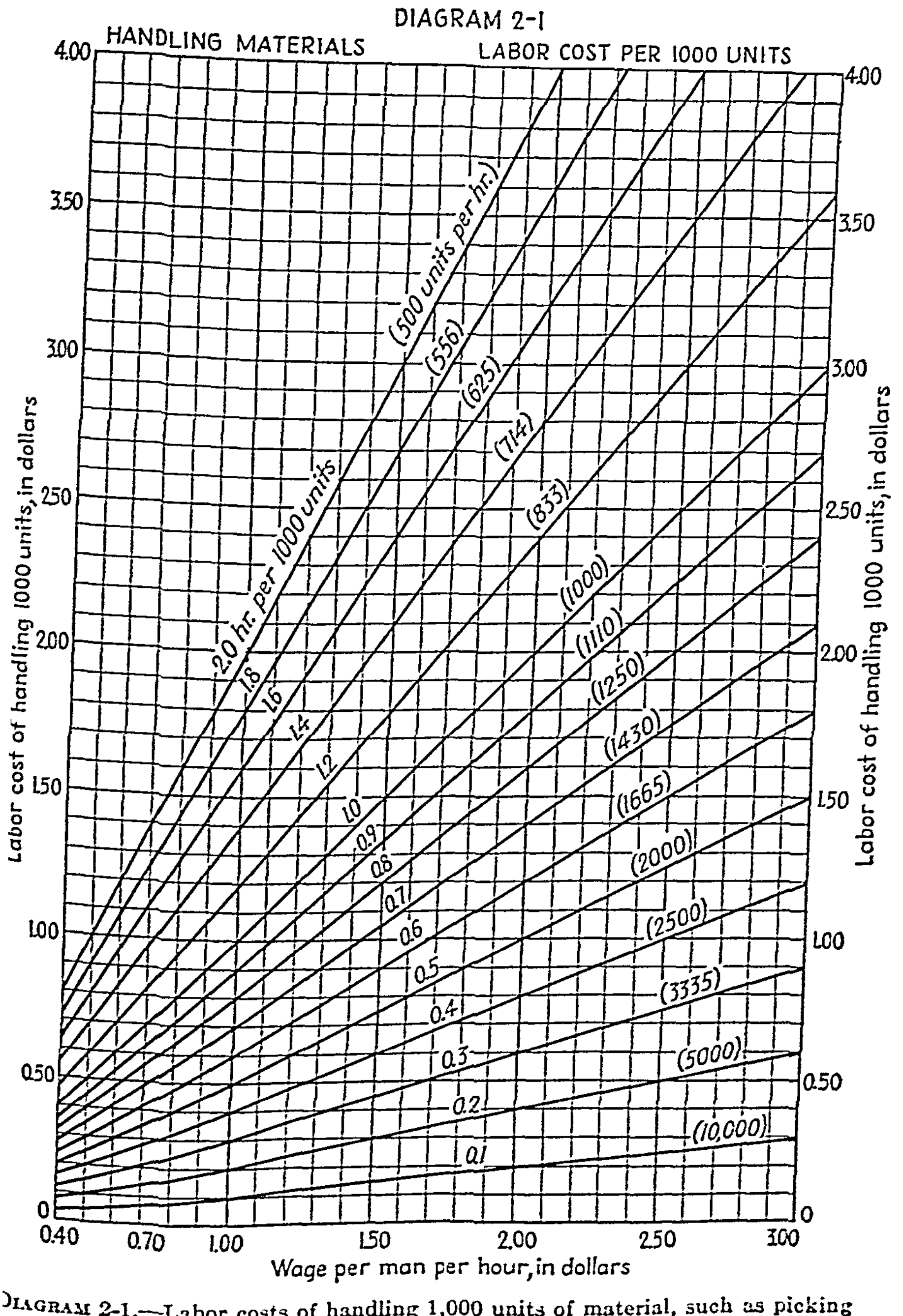

DIAGRAM 2-1.—Labor costs of handling 1,000 units of material, such as picking up materials, taking a few steps and placing or piling.

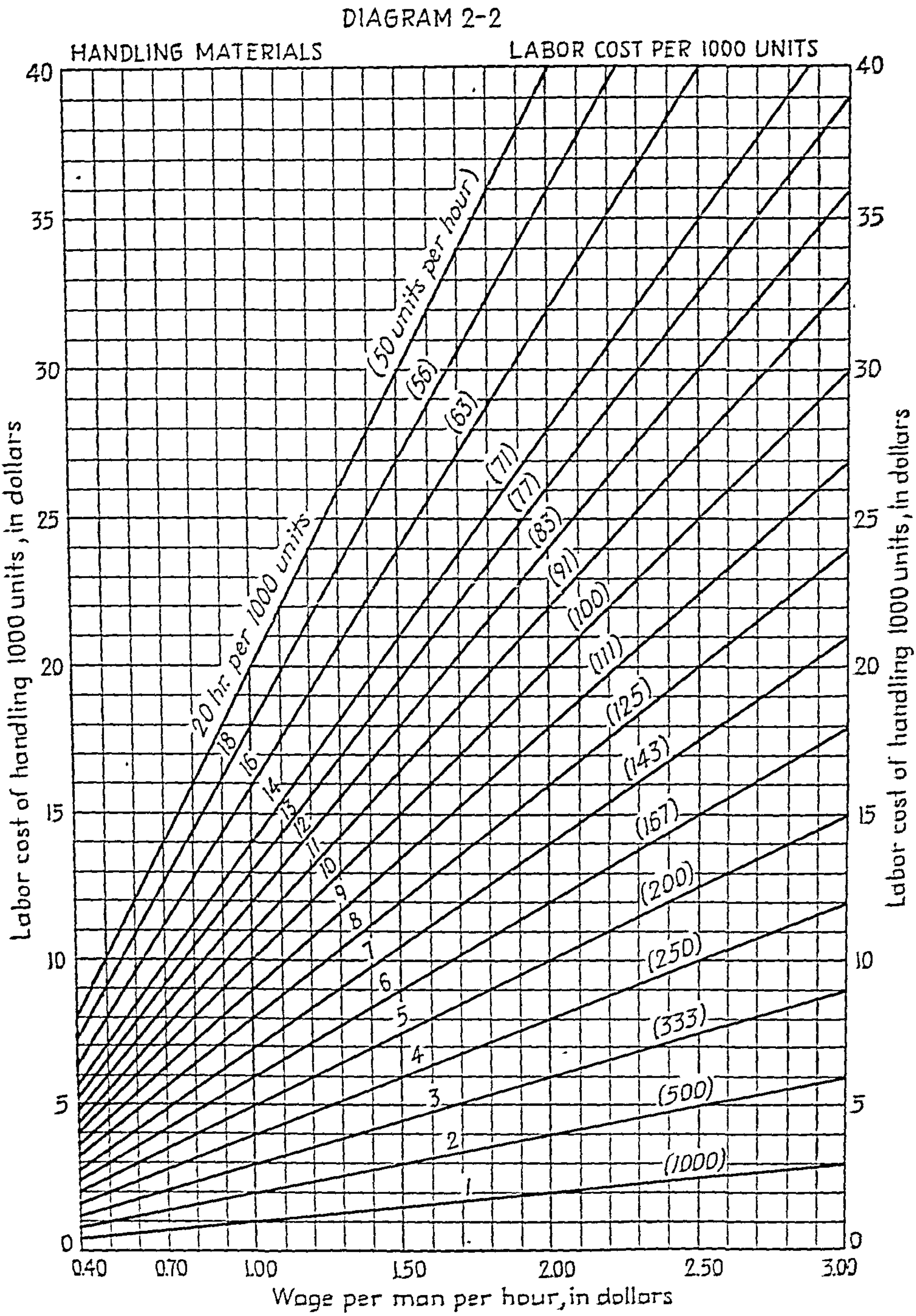

DIAGRAM 2-2.—Labor costs of handling 1,000 units of material, such as picking up materials, taking a few steps, and placing or piling.

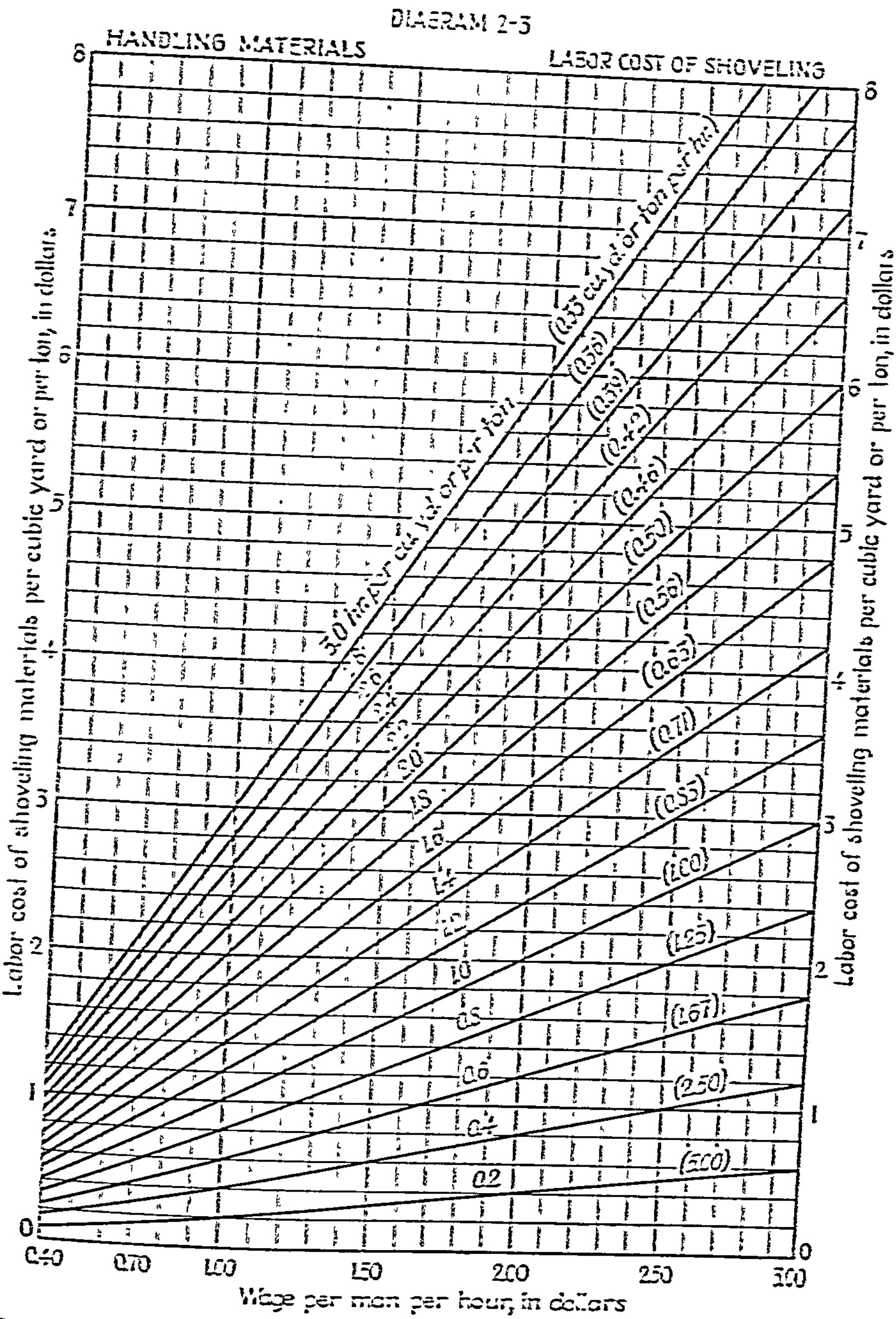

DIAGRAM 2-3.—Labor costs of shoveling materials per cubic yard or per ton.

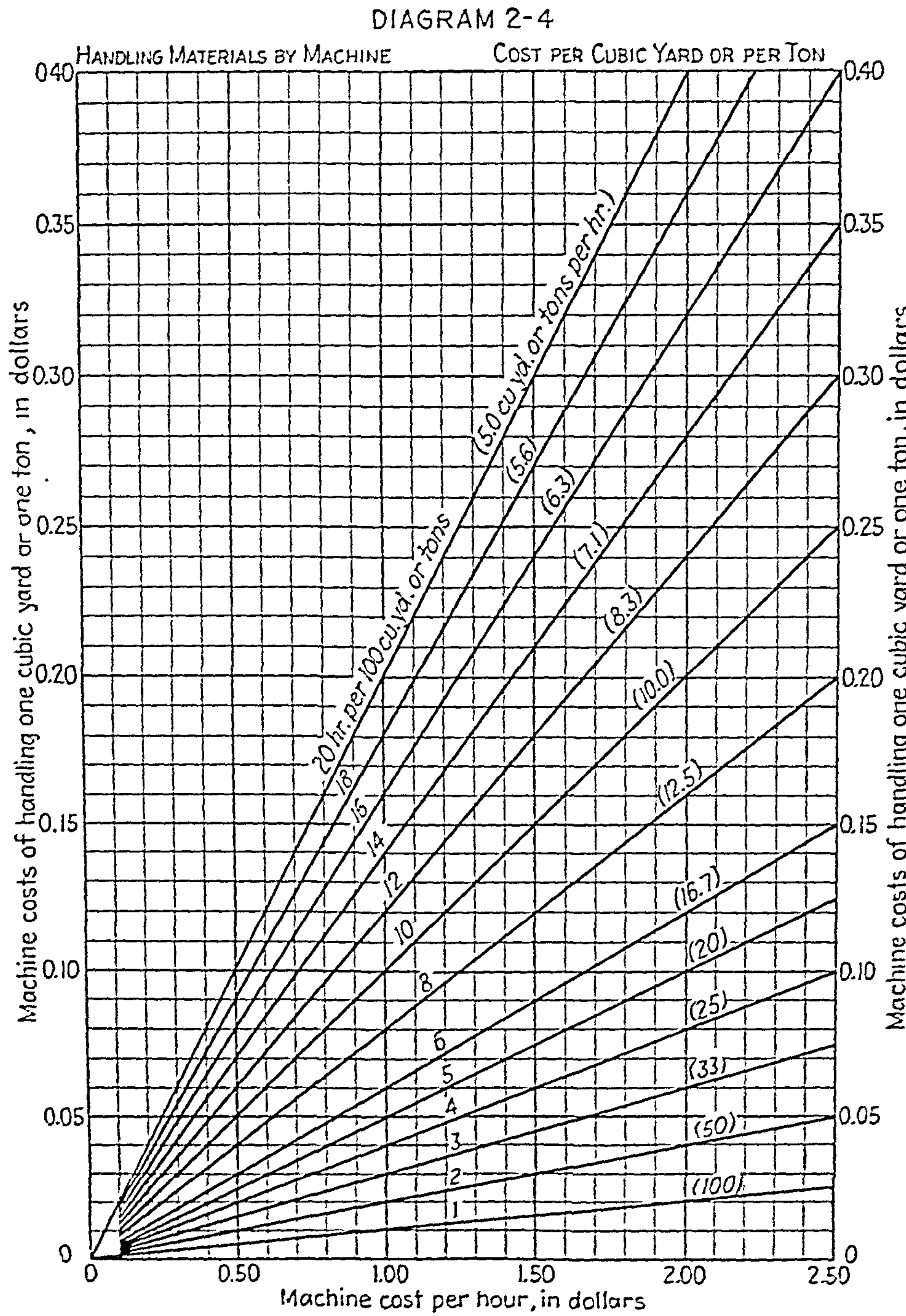

DIAGRAM 2-4.—Machine costs of handling materials per cubic yard or per ton. Machine costs per hour may or may not include cost of operator.

DIAGRAM 2-5

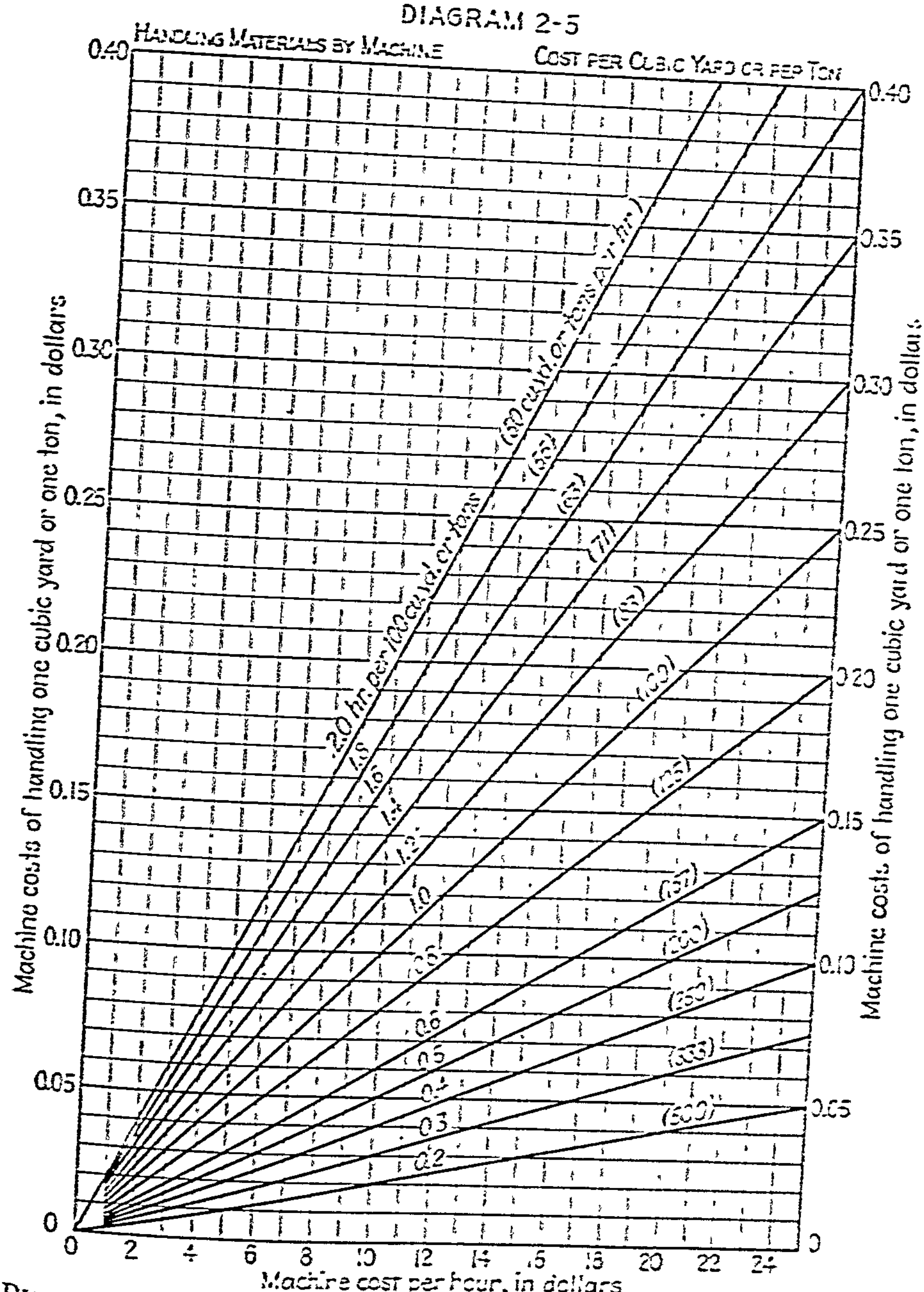

DIAGRAM 2-5.—Machine costs of handling materials per cubic yard or per ton. Machine costs per hour may or may not include cost of operator and crew.

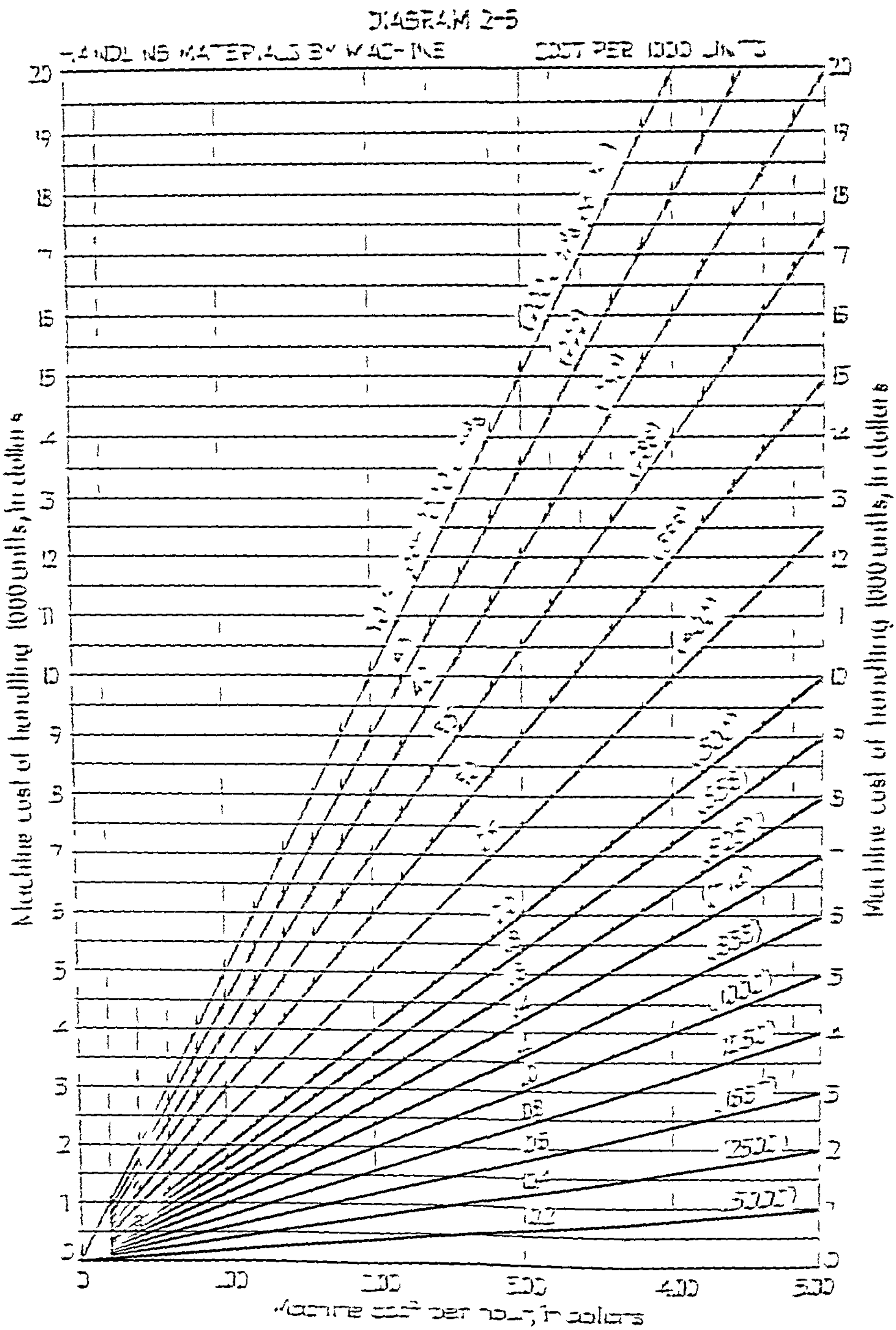

DIAGRAM 2-5.—Machine costs of handling 1,000 units of materials. Machine costs per hour may or may not include cost of operator.

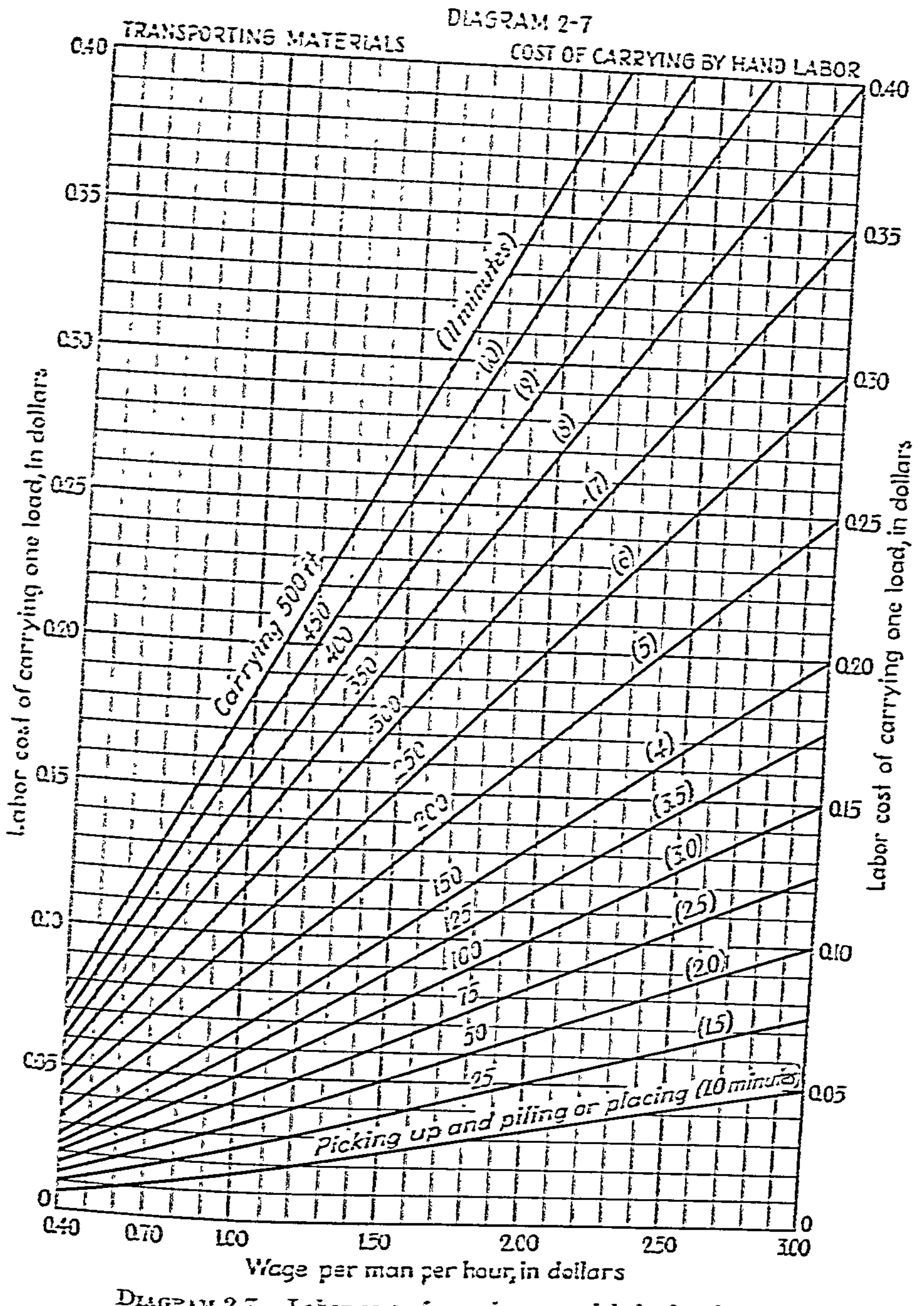

DIAGRAM 2-7.—Labor cost of carrying materials by hand.

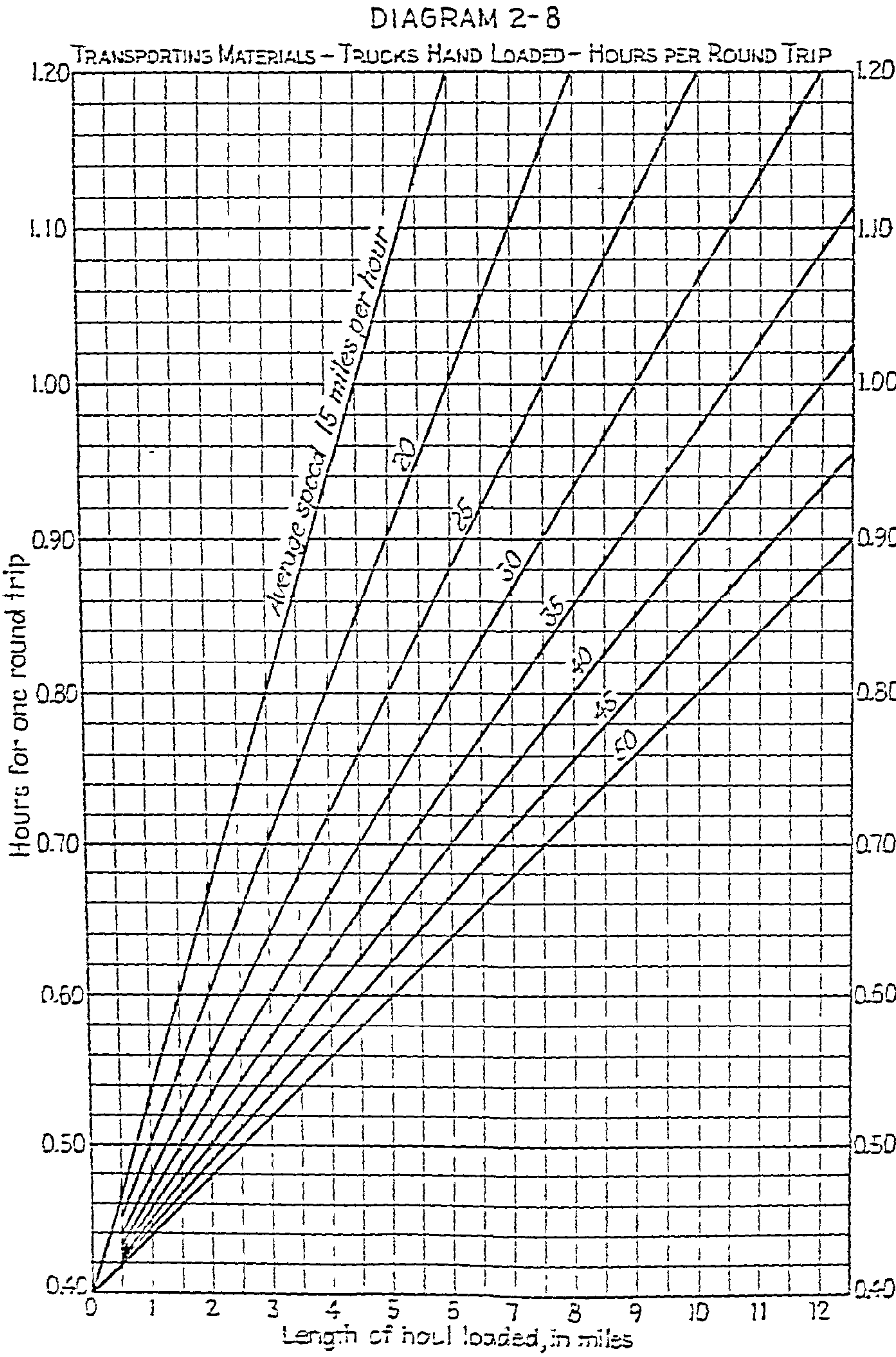

DIAGRAM 2-8.—Hours required per round trip with trucks hand loaded. Time allowed for loading, unloading, and delays is 0.40 hr. or 24 min.

DIAGRAM 2-9

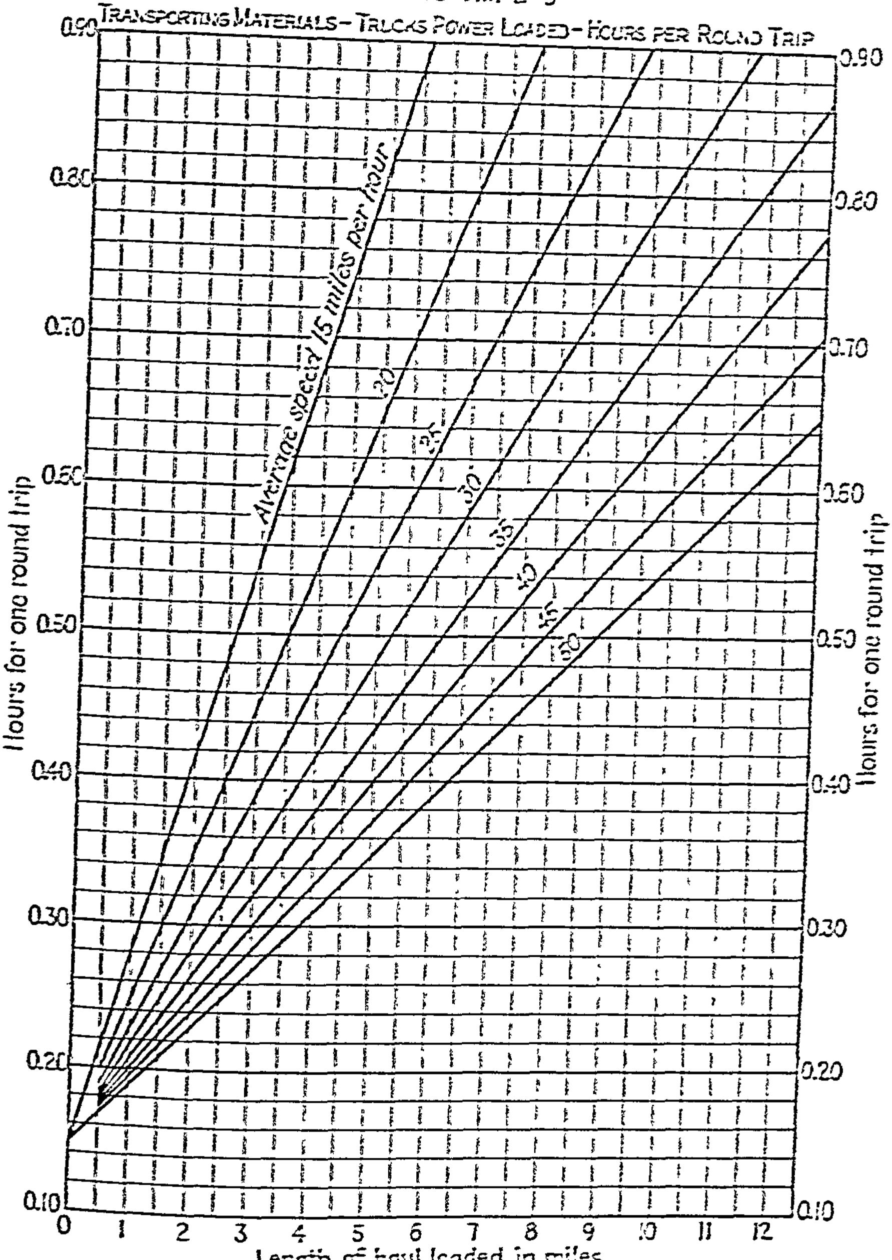

DIAGRAM 2-9.—Hours required per round trip with trucks power loaded. Time allowed for loading, unloading, and delays is 0.15 hr. or 9 min.

DIAGRAM 2-10

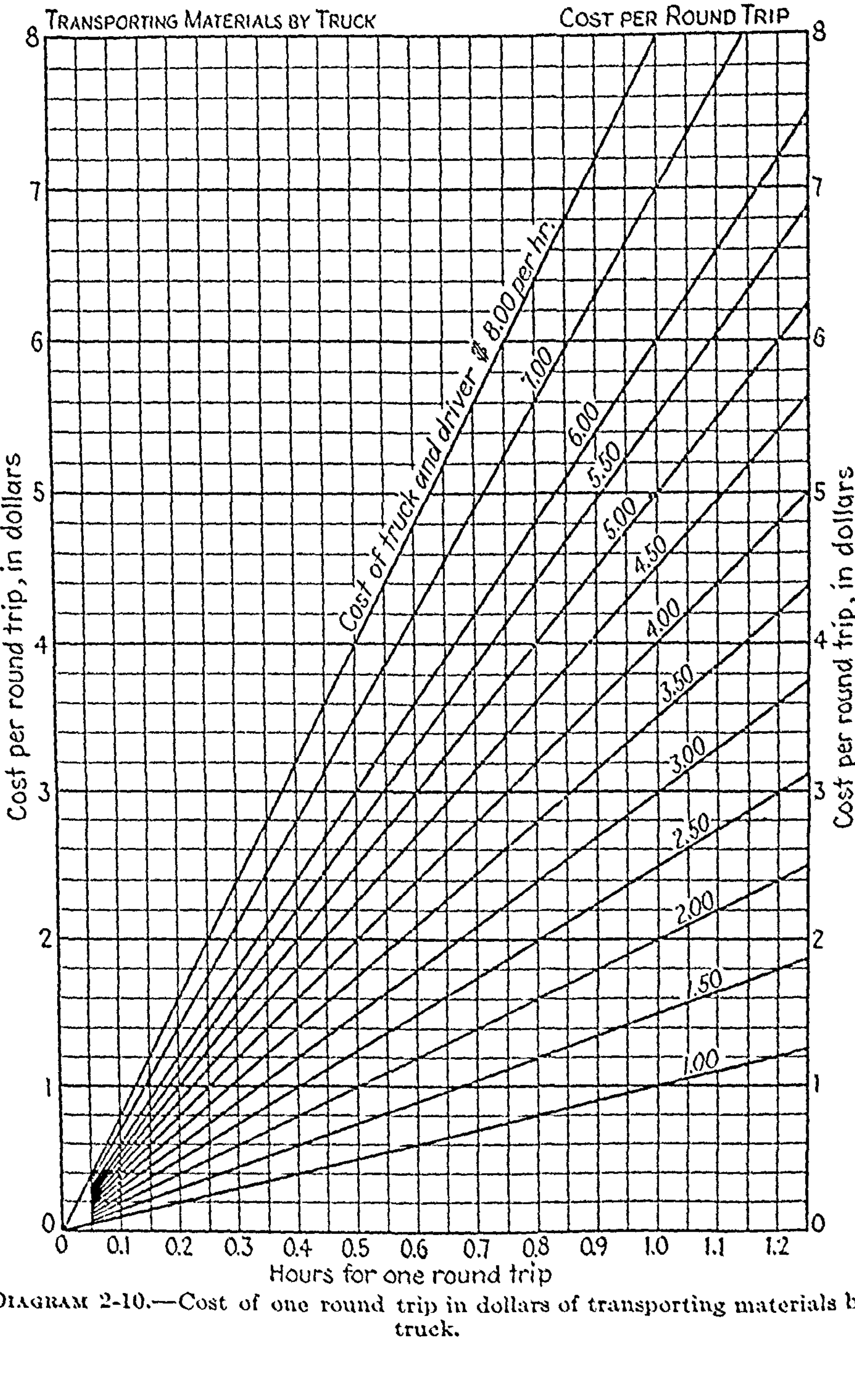

DIAGRAM 2-10.—Cost of one round trip in dollars of transporting materials by truck.

DIAGRAM 2-11

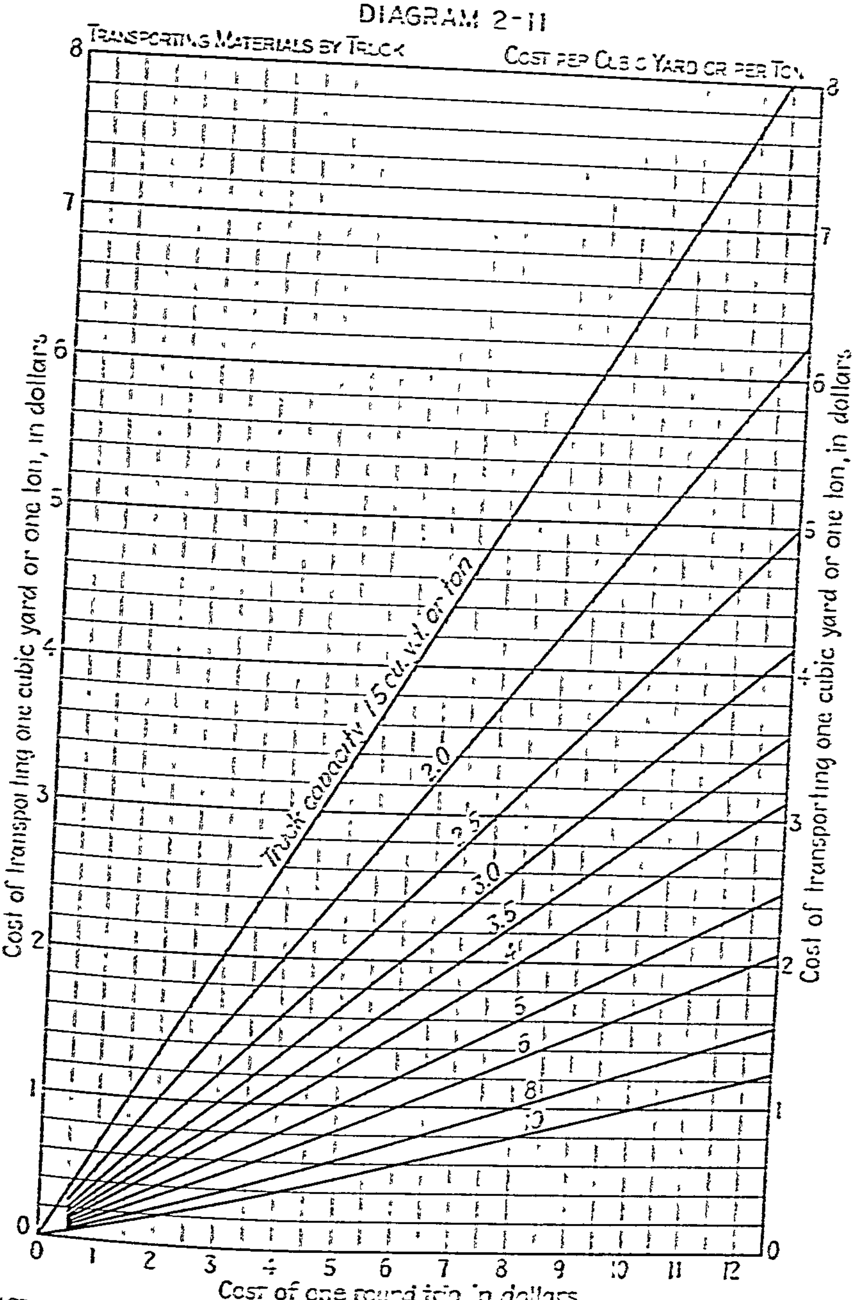

DIAGRAM 2-11.—Cost of transporting 1 cu. yd. or ton of materials by truck.

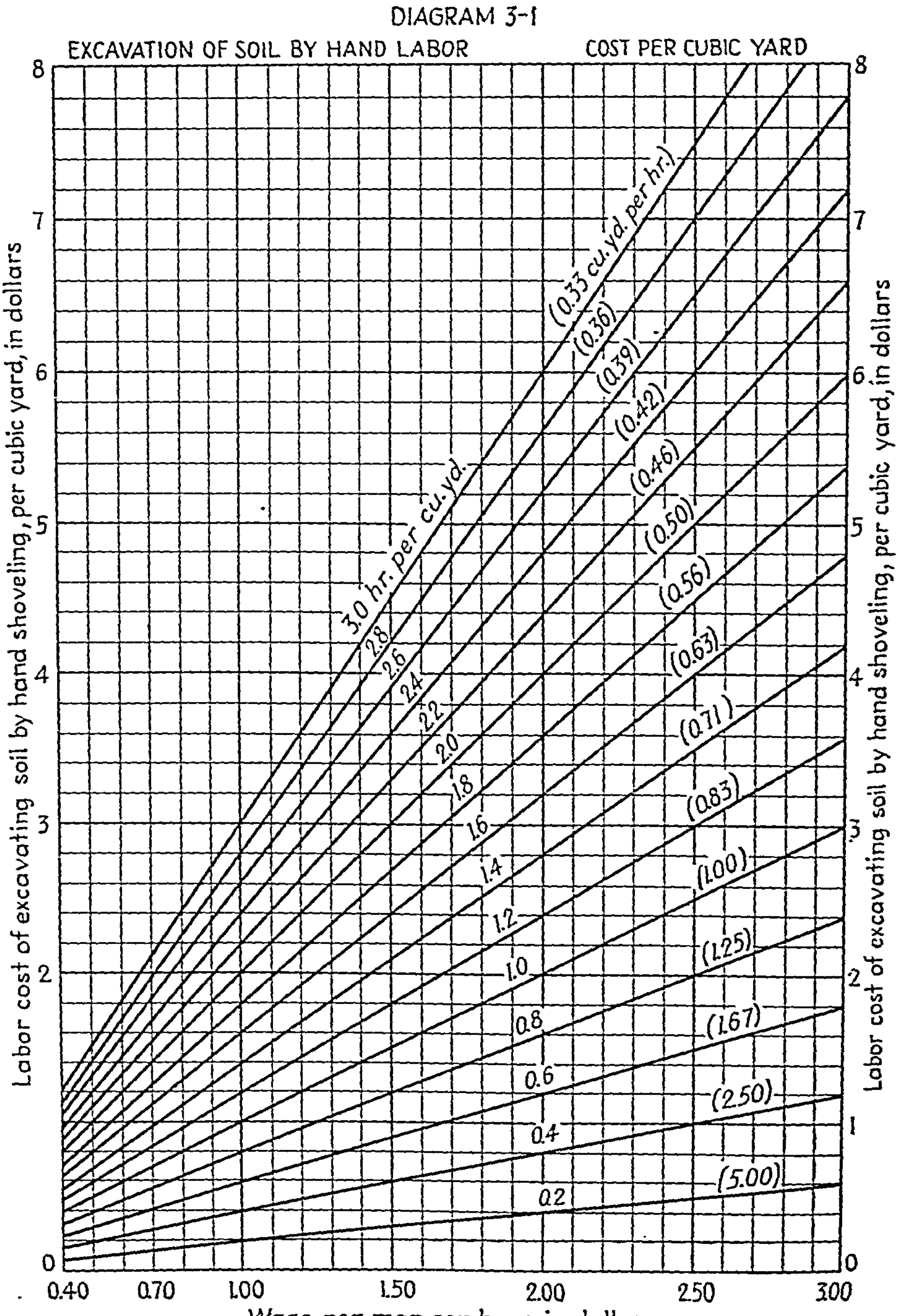

DIAGRAM 3-1.—Labor cost of excavating soil by hand shoveling. This diagram may be used for estimating costs of excavation by hand shoveling, trenching by hand labor, excavation by hand labor and wheelbarrows, backfilling by hand labor, and spreading soil by hand labor.

DIAGRAM 3-2

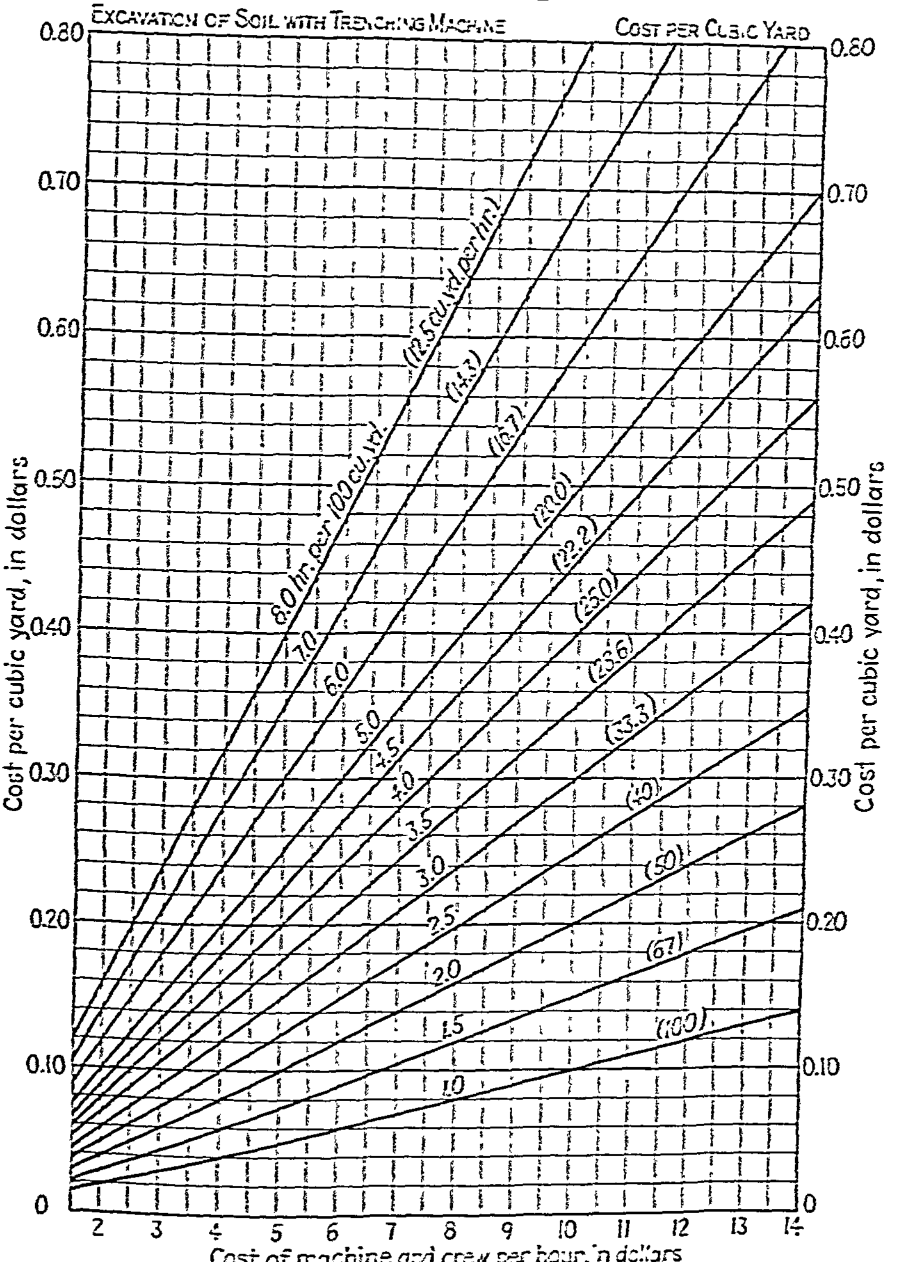

DIAGRAM 3-2.—Cost per cubic yard of trenching and backfilling by machine and crew. Cost of transporting machine to and from the job is not included.

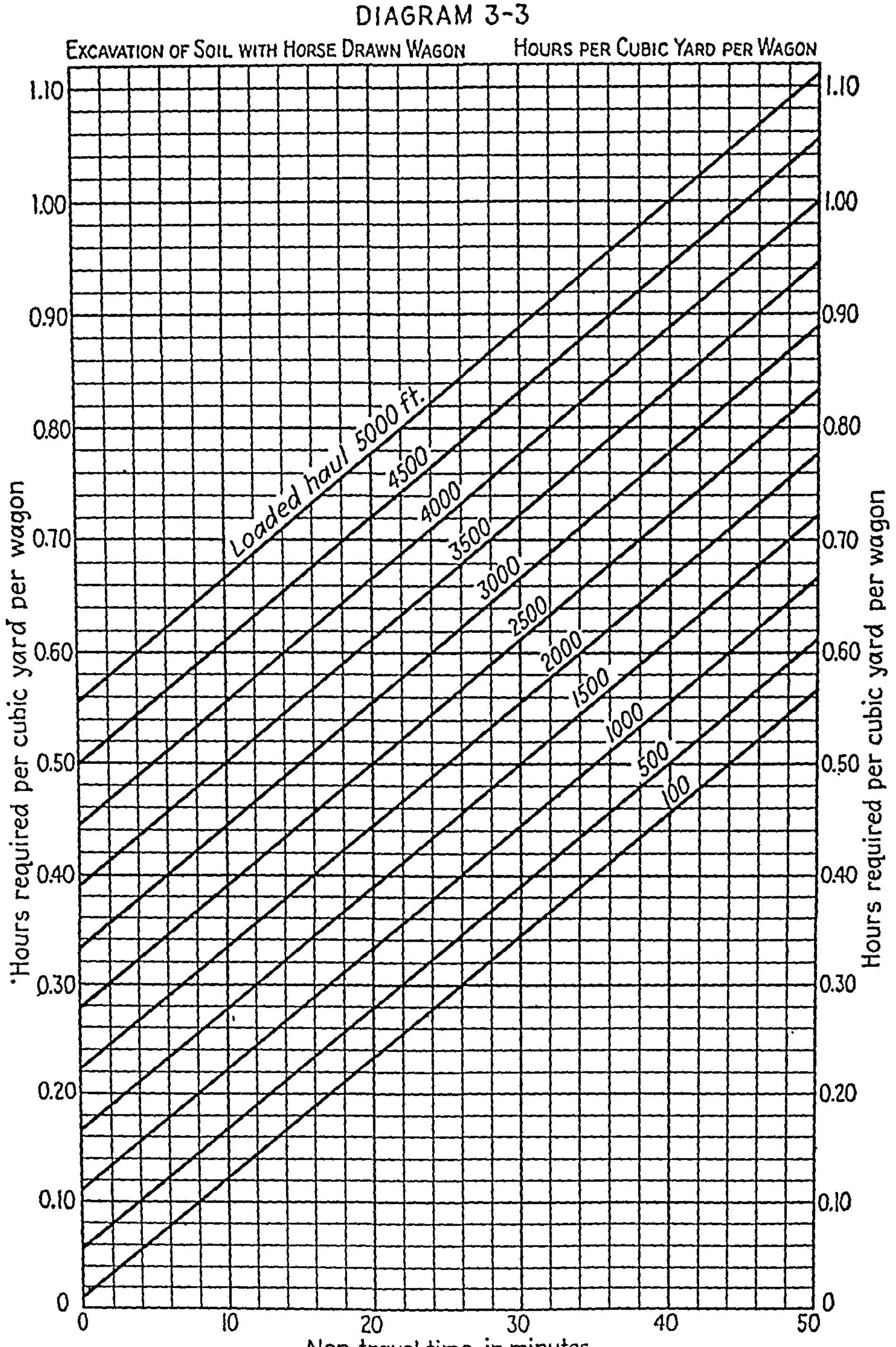

DIAGRAM 3-3.—Relations between length of haul loaded in feet, non-travel time (load, unload, and delays) in minutes, and hours required for an output of 1 cu. yd. per wagon for two-horse dump wagons of 2.0 cu. yd. rated or 1.5 cu. yd. net capacity.

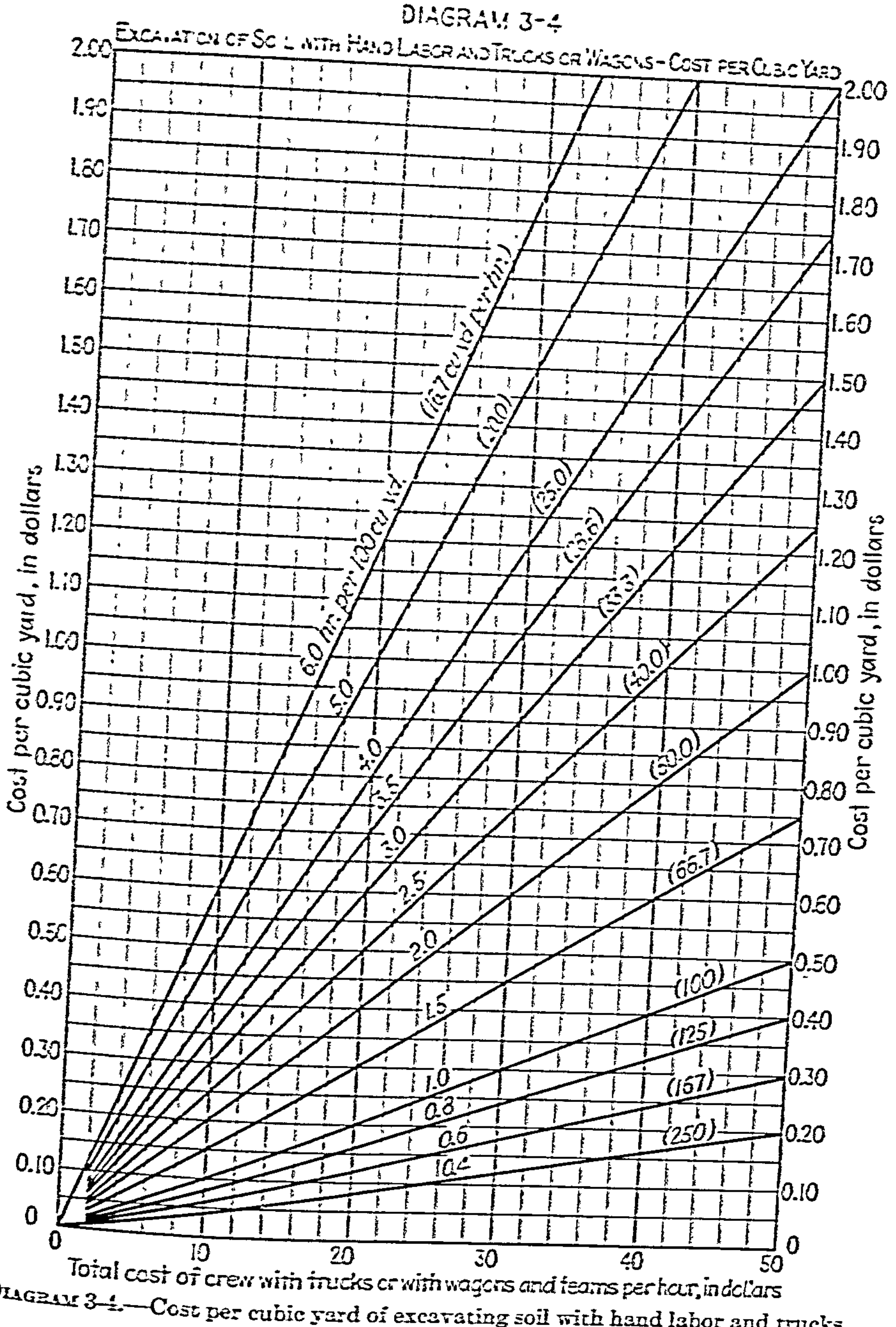

DIAGRAM 3-4.—Cost per cubic yard of excavating soil with hand labor and trucks or with wagons and teams.

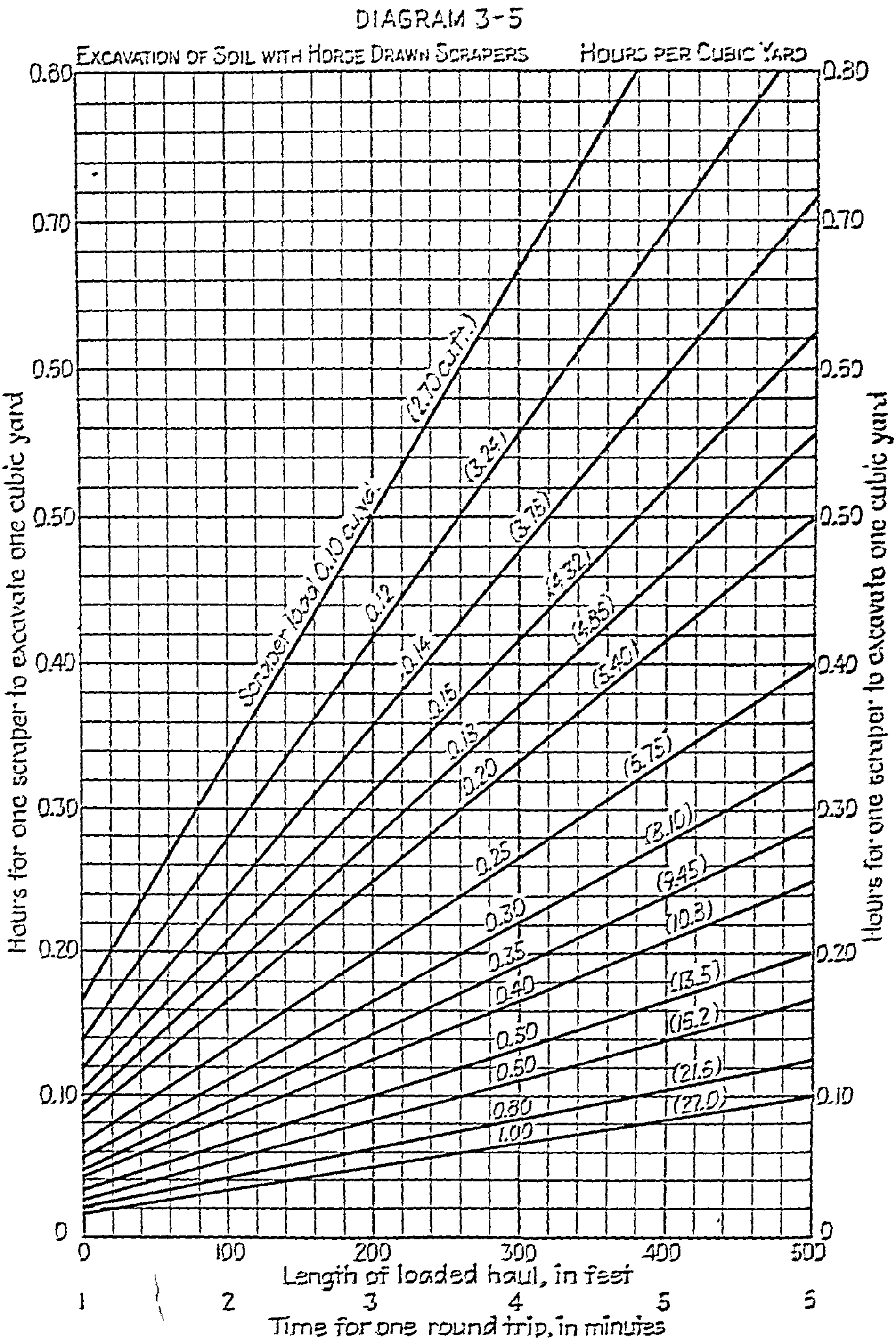

DIAGRAM 3-5.—Excavation of soil by horse-drawn scrapers. Hours per cubic yard per scraper.

DIAGRAM 3-6

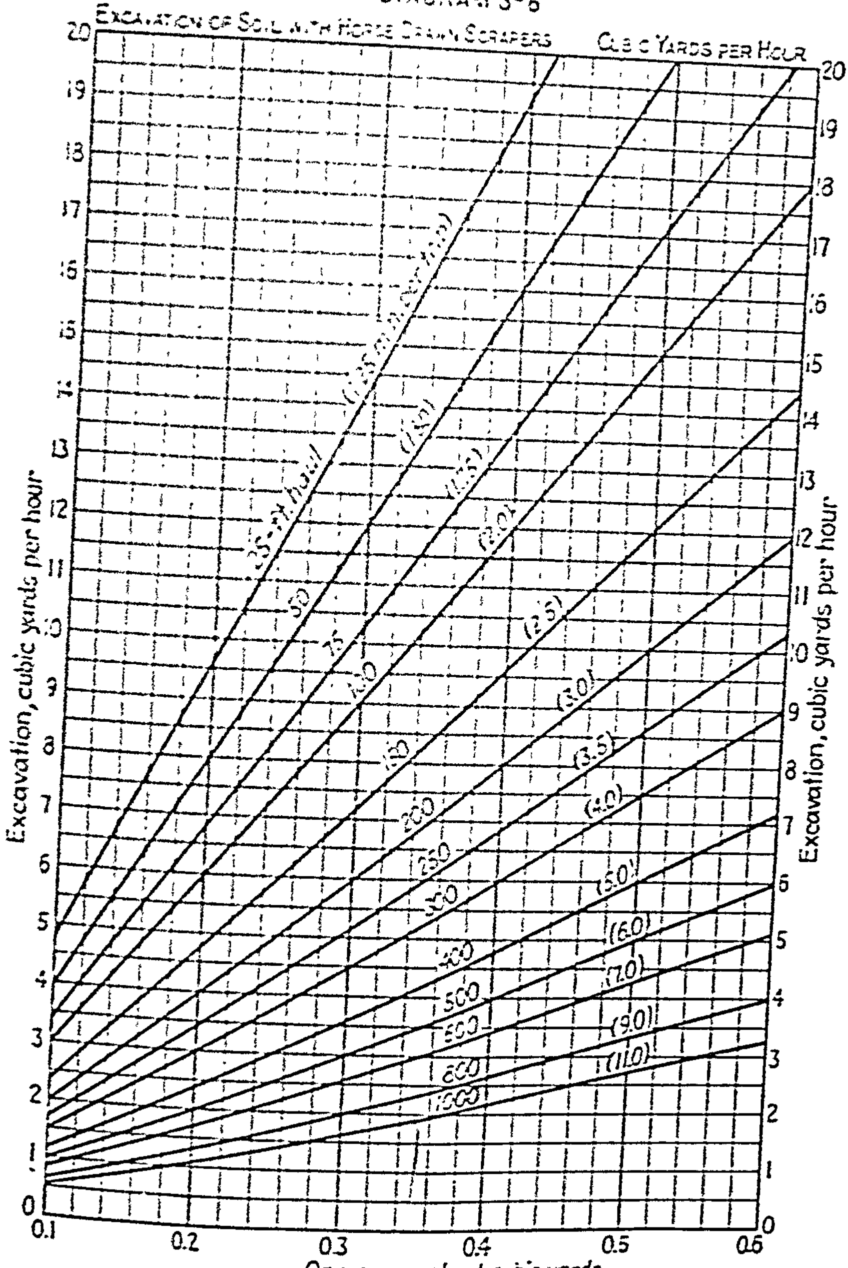

DIAGRAM 3-6.—Excavation of soil by horse-drawn scrapers. Cubic yards per hour per scraper.

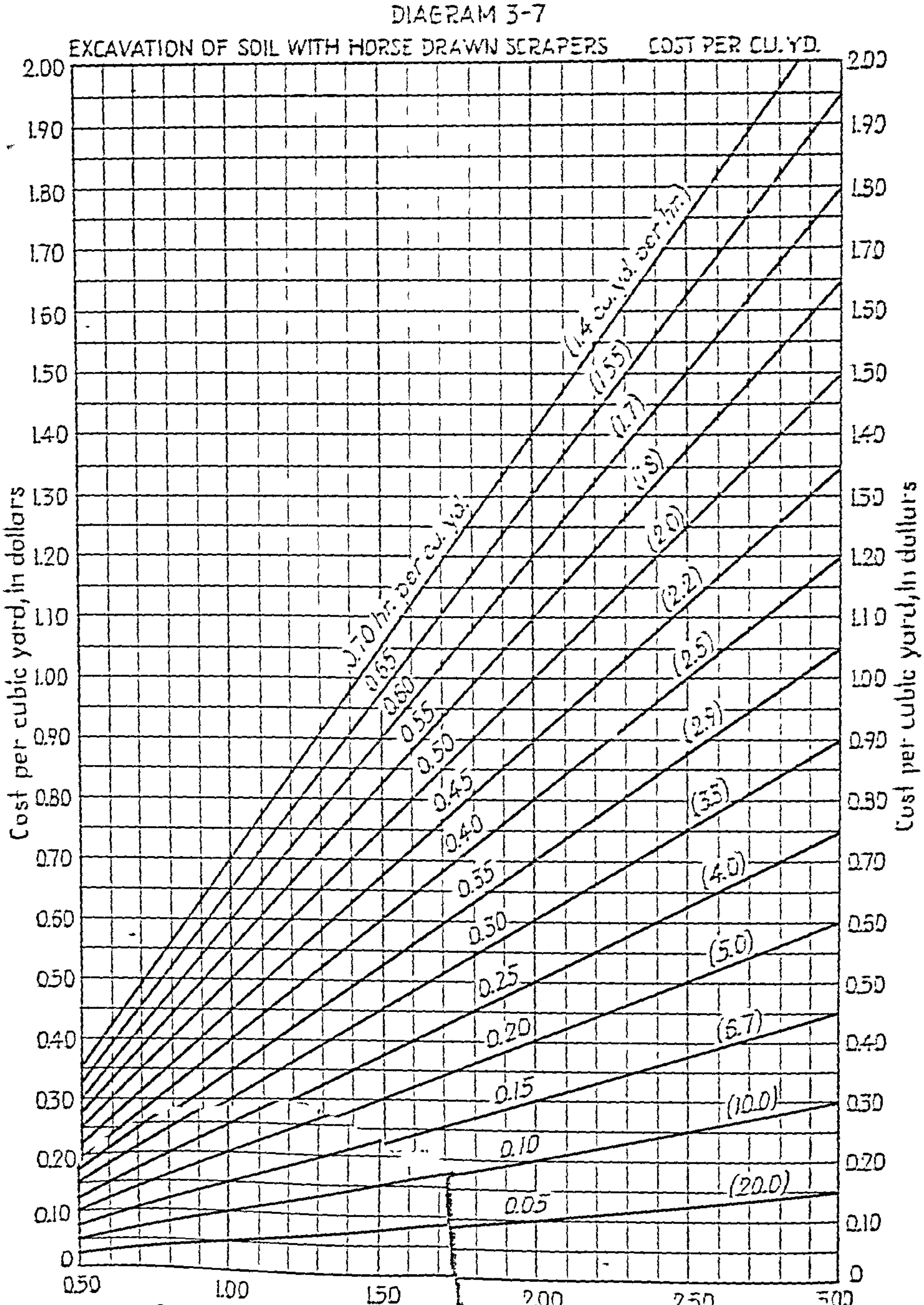

DIAGRAM 3-7.—Cost per cubic yard of excavating soil with horse-drawn scrapers.

DIAGRAM 3-8

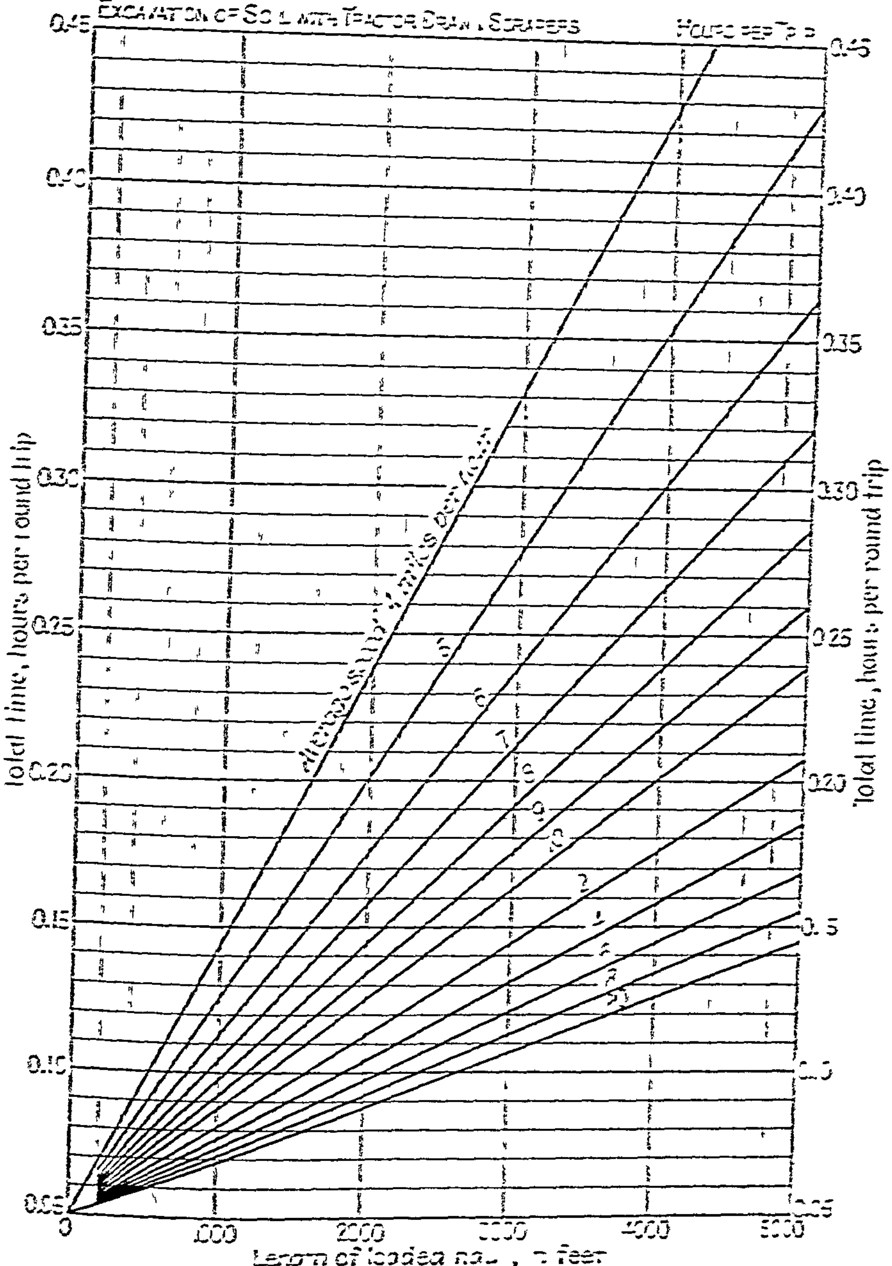

DIAGRAM 3-8.—Hours per round trip required for tractor-drawn scrapers with an allowance of 0.05 hr. (3 min.) per round trip for loading, unloading, turning, and minor delays.

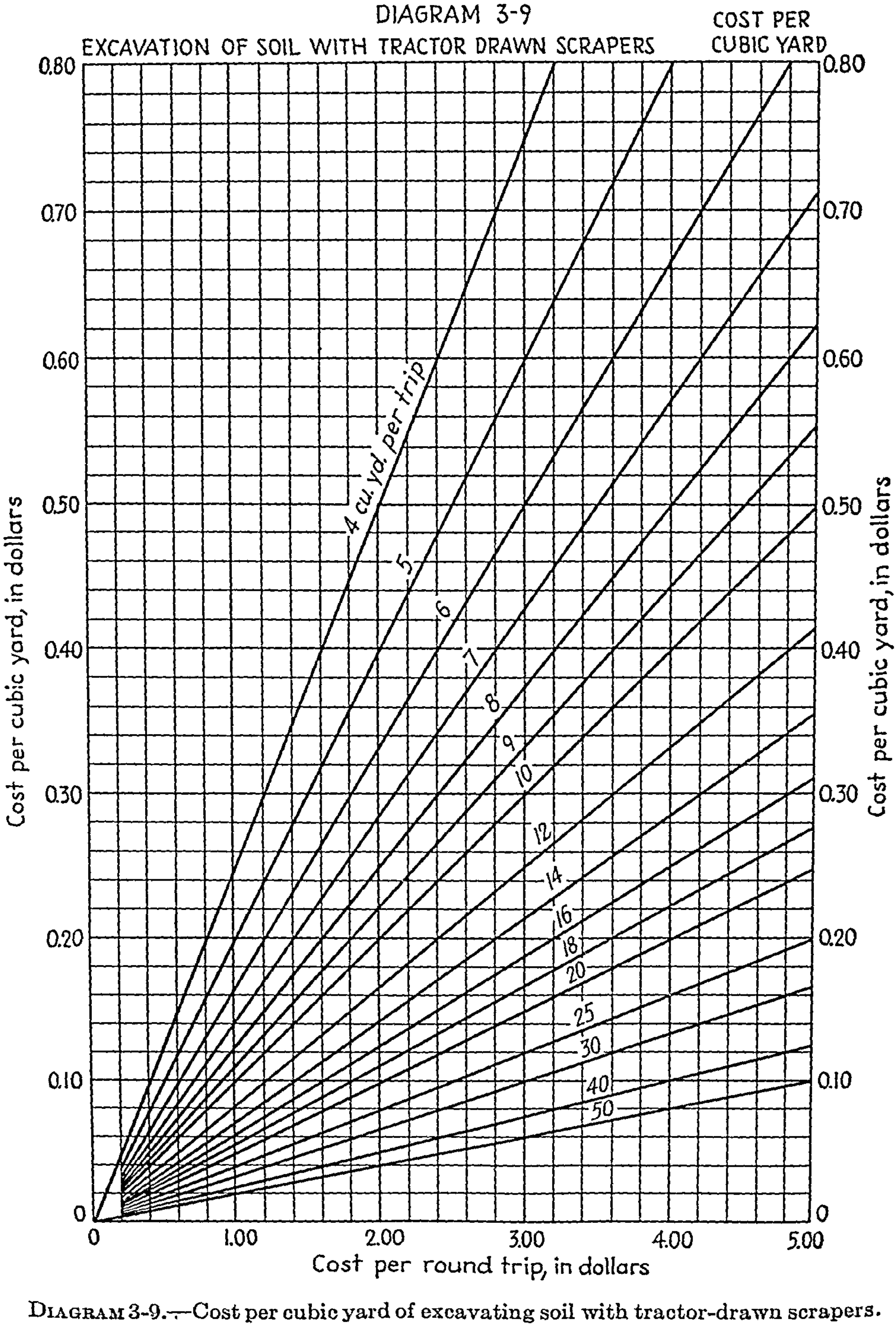

DIAGRAM 3-9.—Cost per cubic yard of excavating soil with tractor-drawn scrapers.

DIAGRAM 3-10

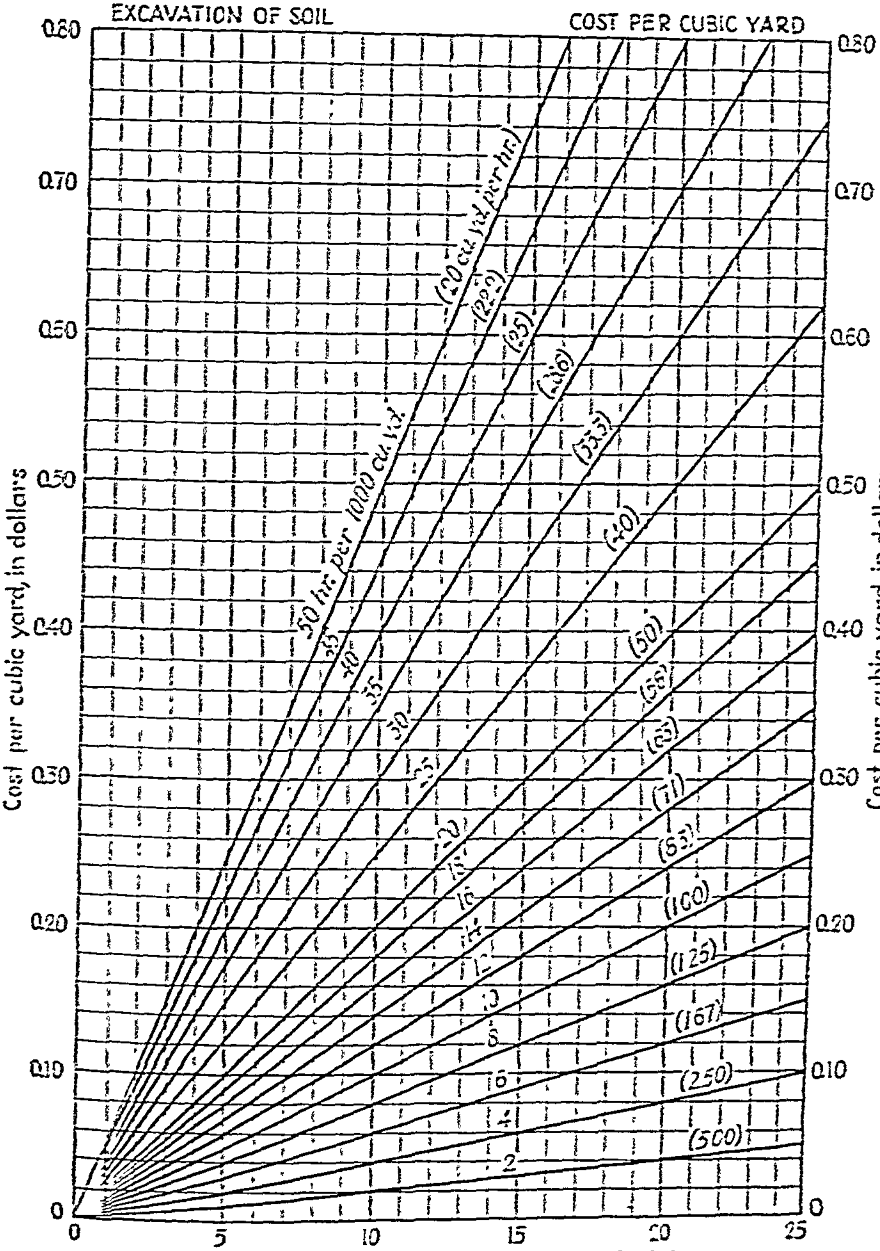

DIAGRAM 3-10.—Cost per cubic yard of transporting soil with power equipment.

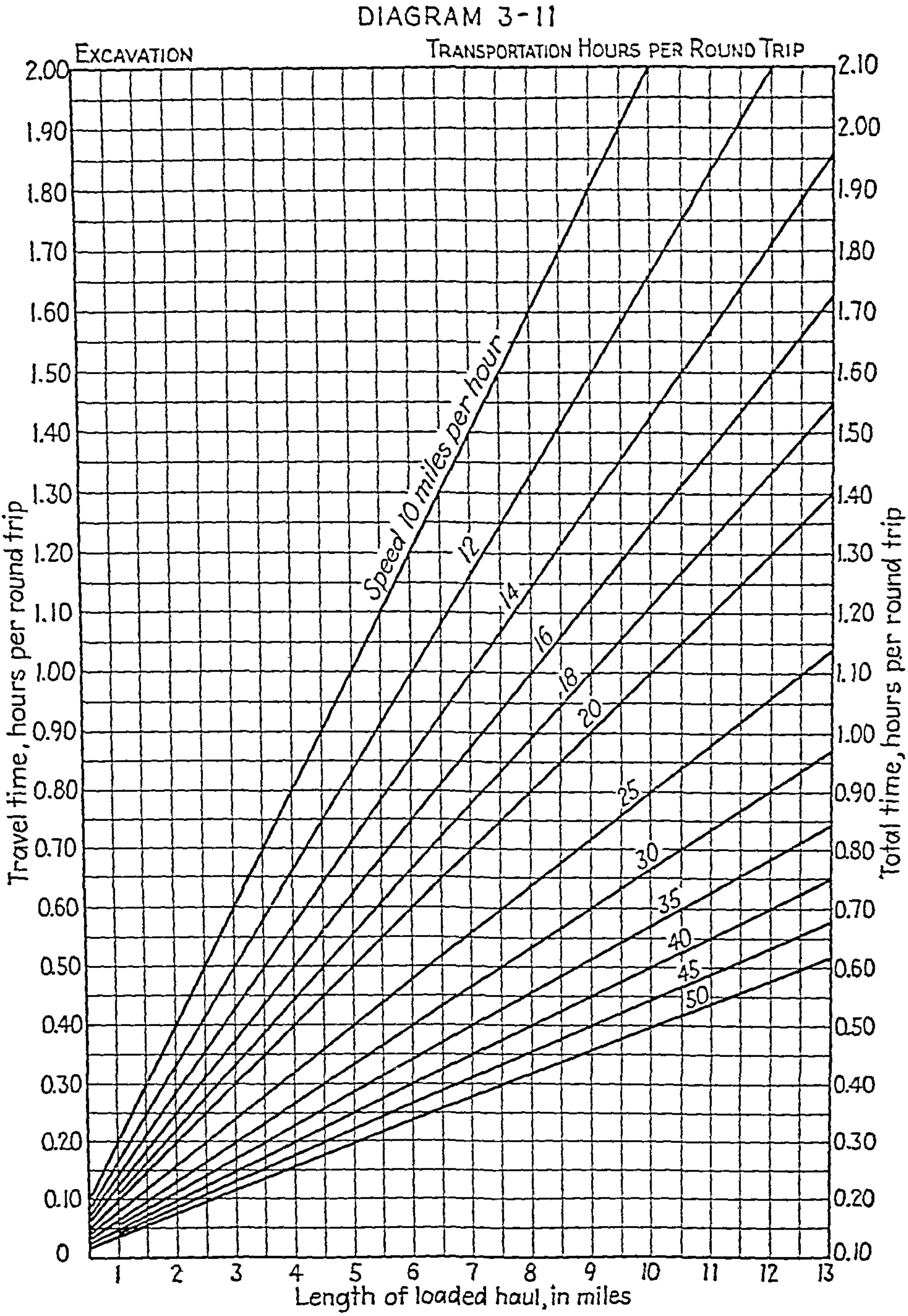

DIAGRAM 3-11.—Time in hours required for one round trip for transporting soil. Left-hand scale shows travel time only. Right-hand scale shows total time including 0.10 hr. for loading, unloading, and minor delays.

DIAGRAM 3-12

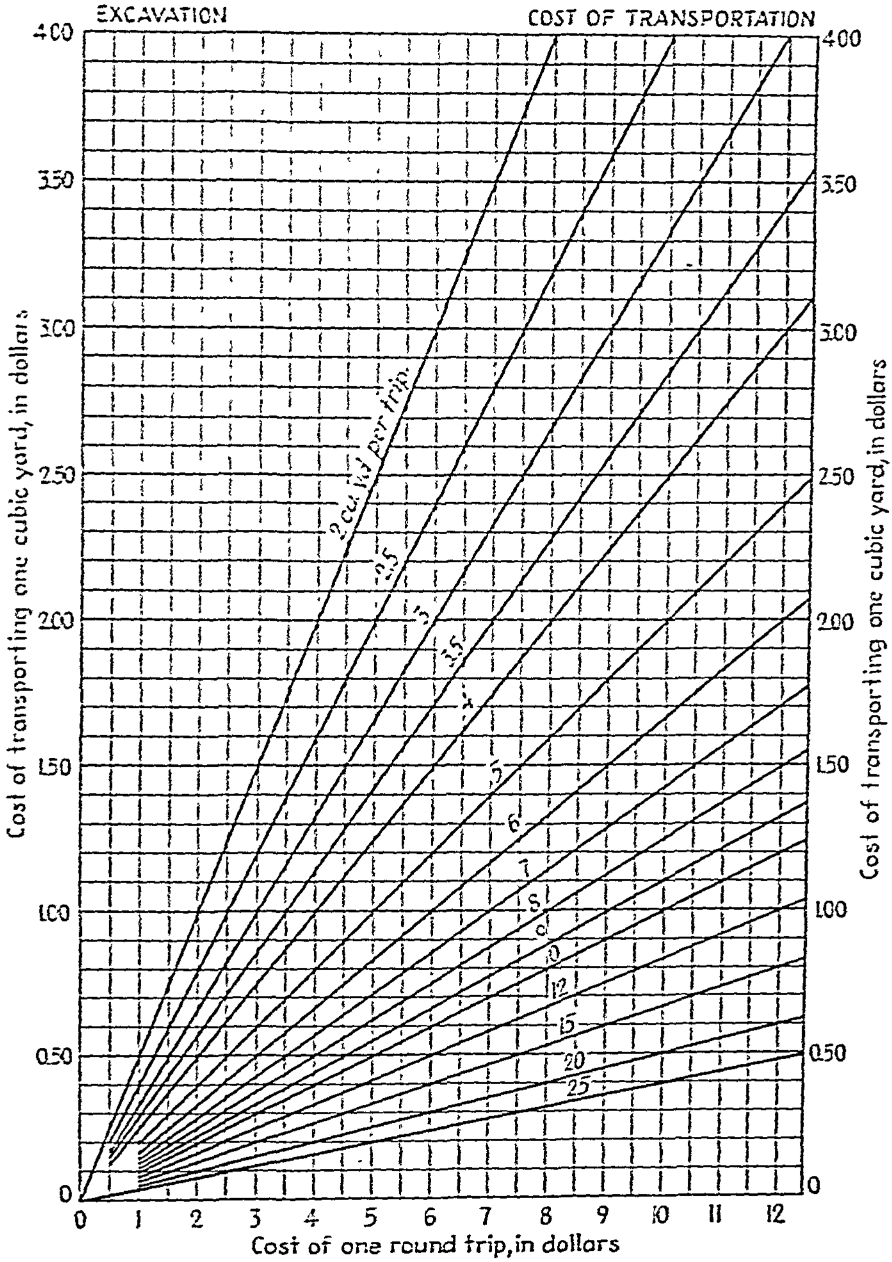

DIAGRAM 3-12.—Cost per cubic yard of transporting soil.

DIAGRAM 3-13

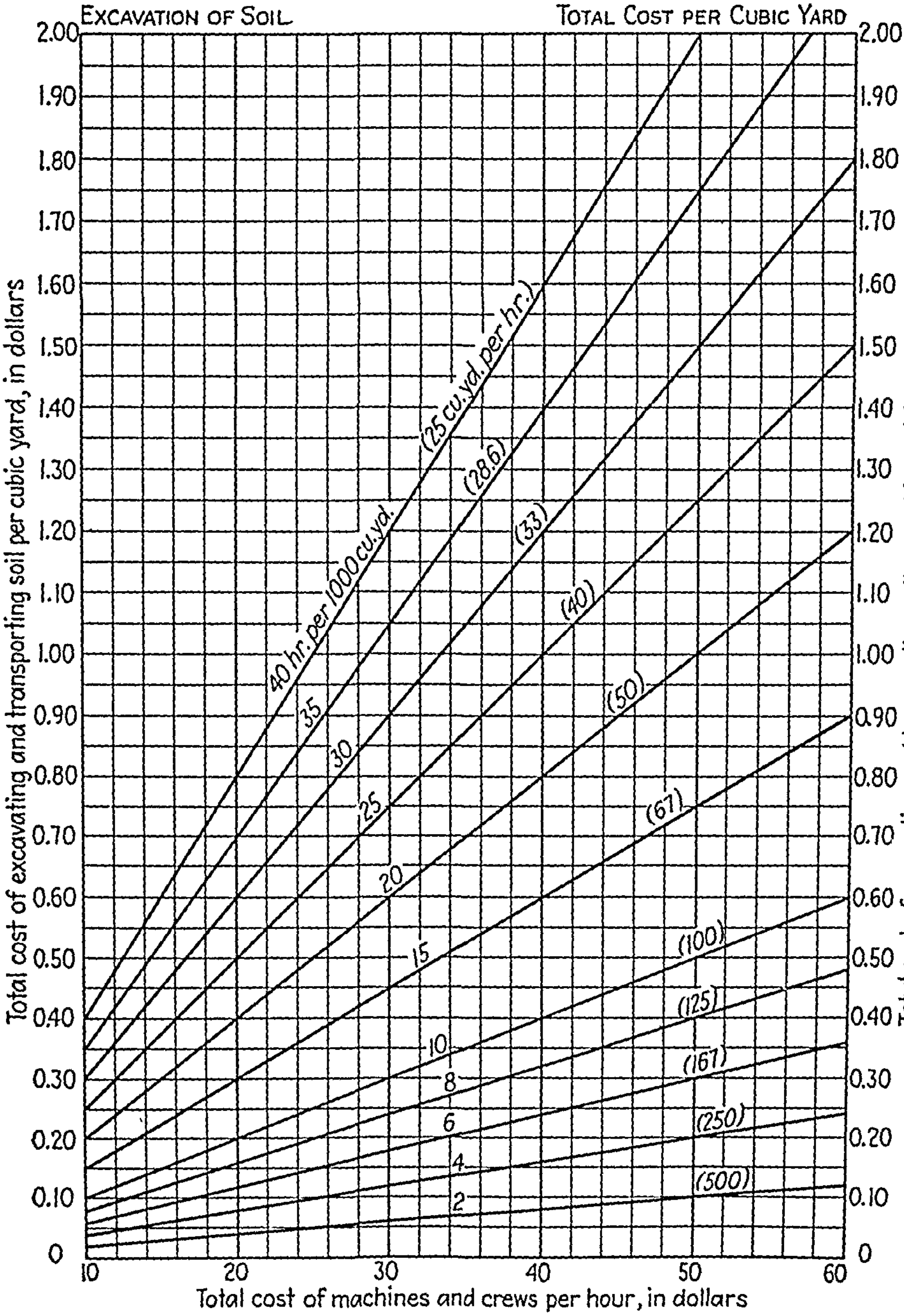

DIAGRAM 3-13.—Total cost per cubic yard of excavating and transporting soil with all power equipment.

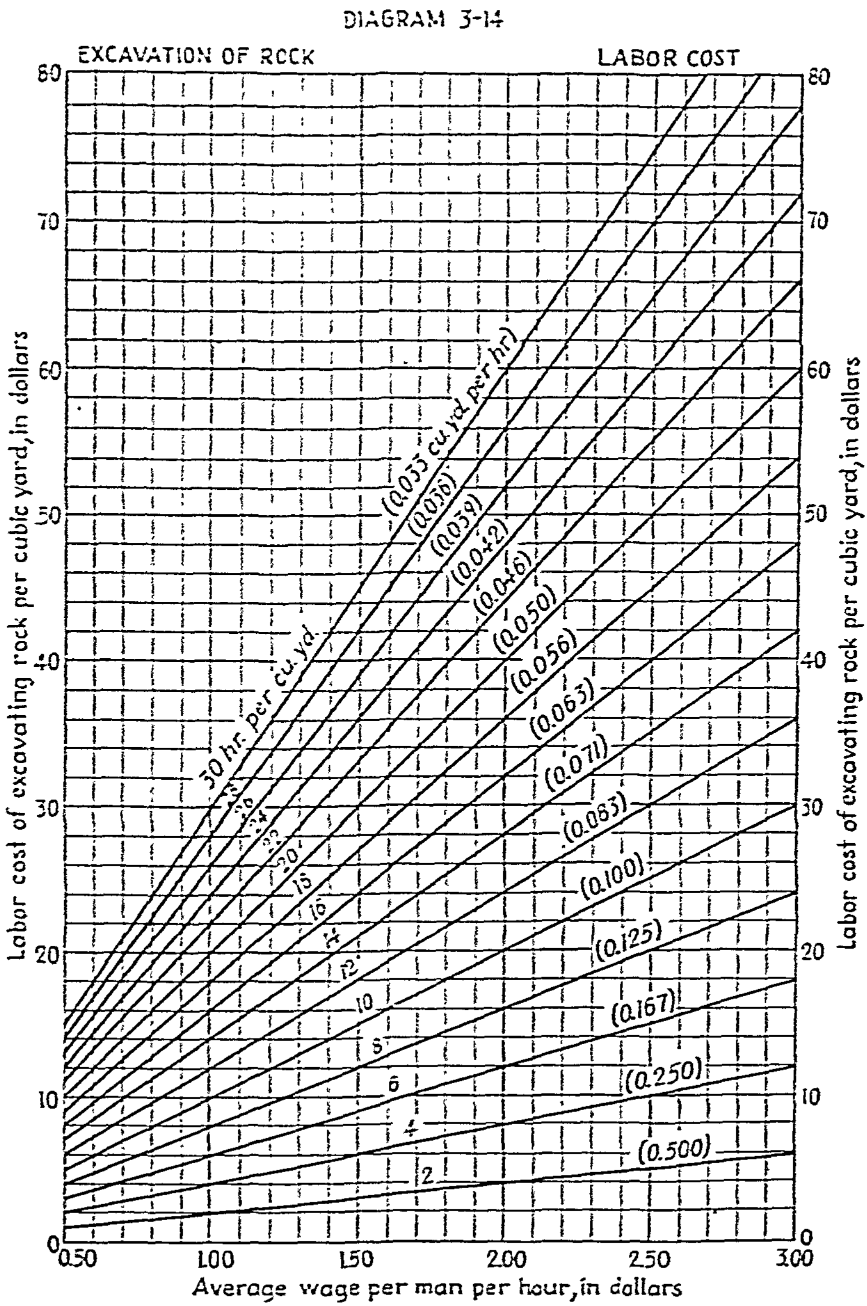

Diagram 3-14.—Labor cost per cubic yard of excavating solid rock.

DIAGRAM 4-1

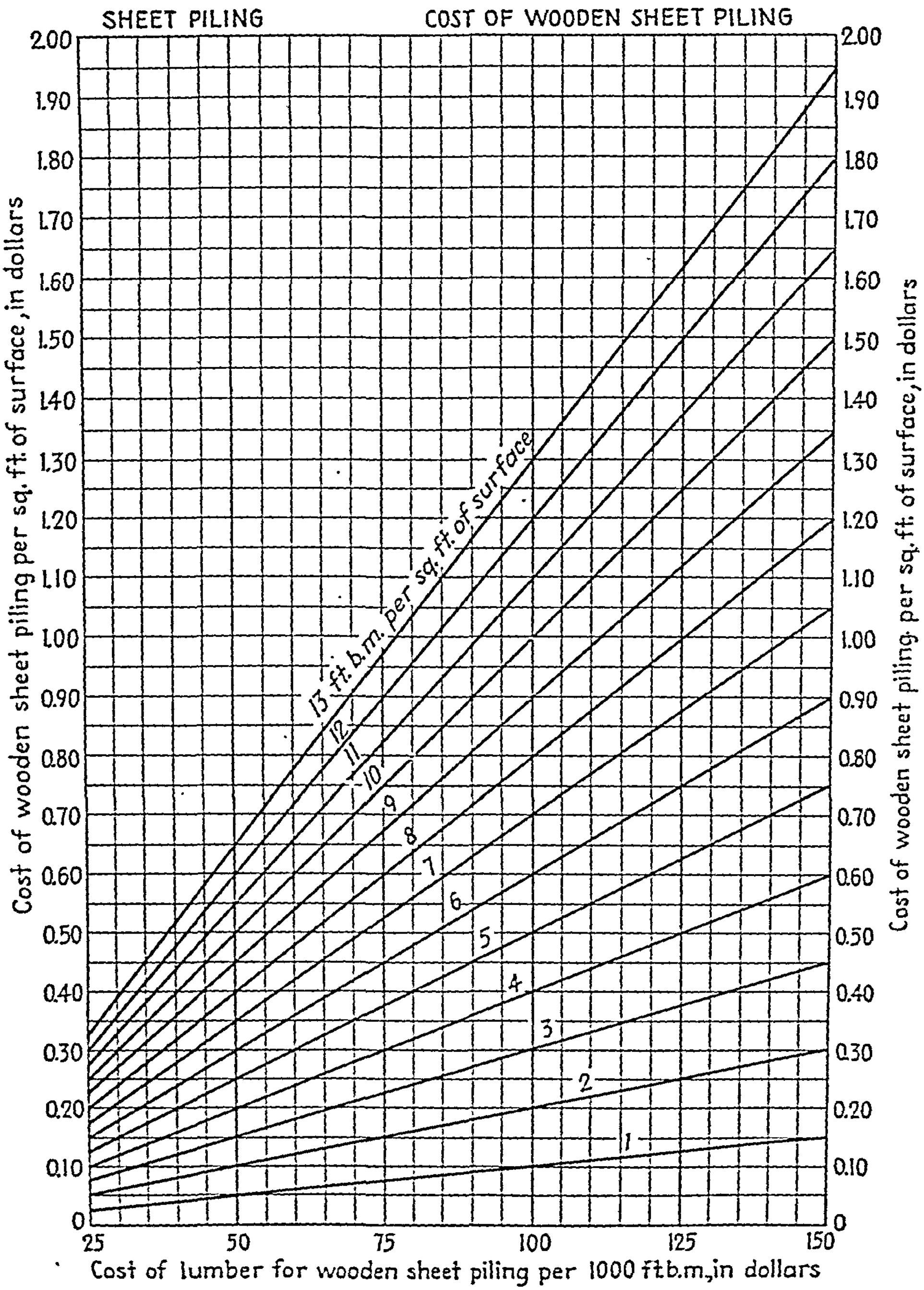

DIAGRAM 4-1.—Lumber cost of wooden sheet piling per square foot of surface.

DIAGRAM 4-2

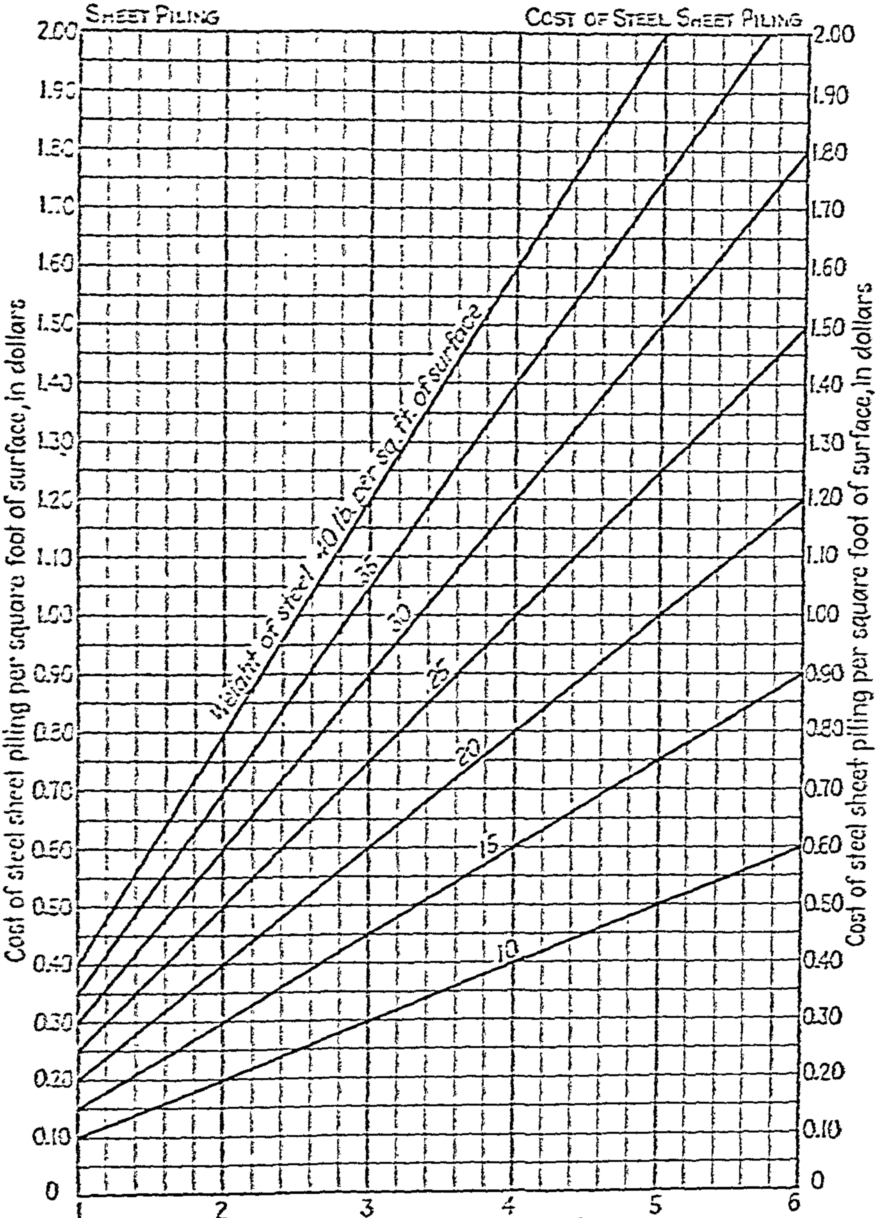

DIAGRAM 4-2.—Cost of steel sheet piling per square foot of surface.

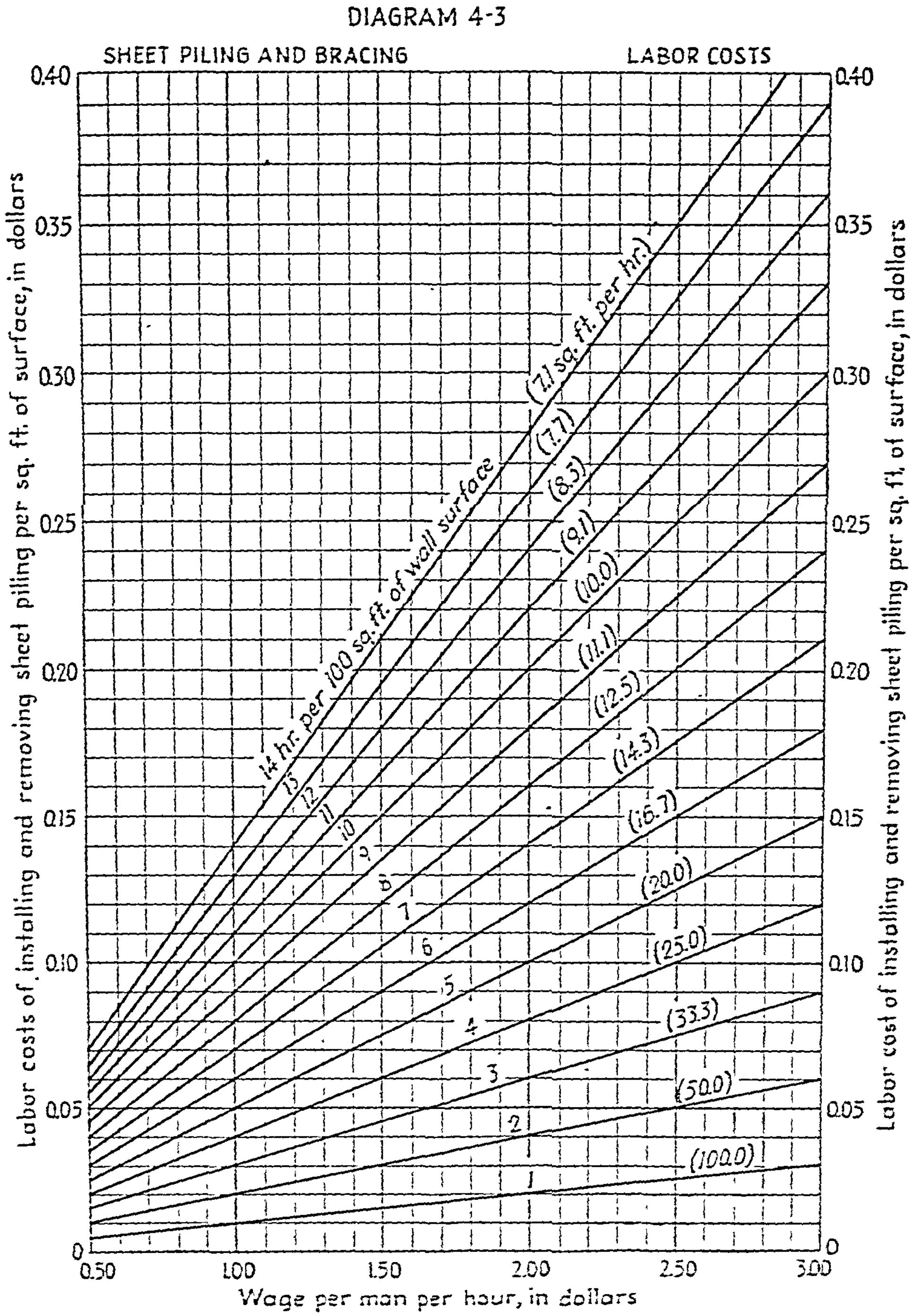

DIAGRAM 4-3.—Labor costs per square foot of surface of installing and removing sheet piling.

DIAGRAM 4-4

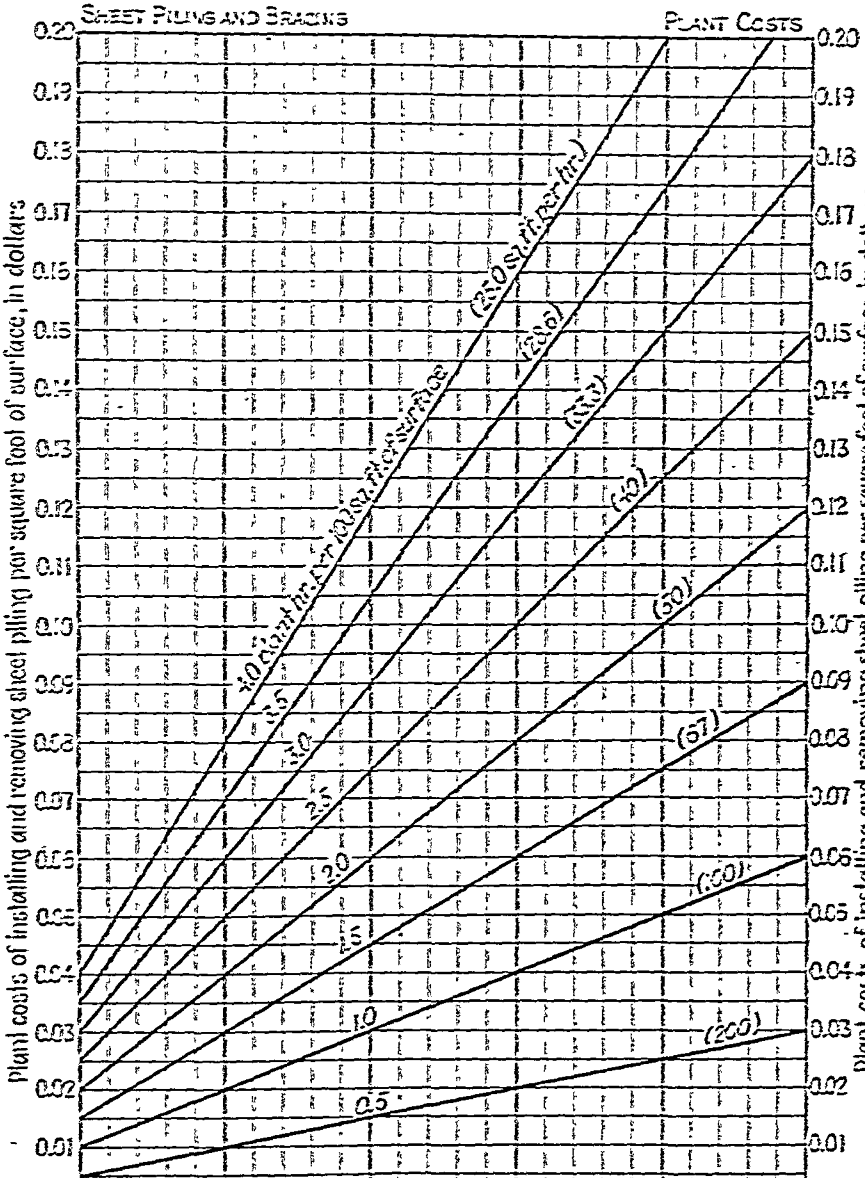

DIAGRAM 4-4.—Plant or equipment costs per square foot of surface for installing and removing sheet piling.

DIAGRAM 4-5

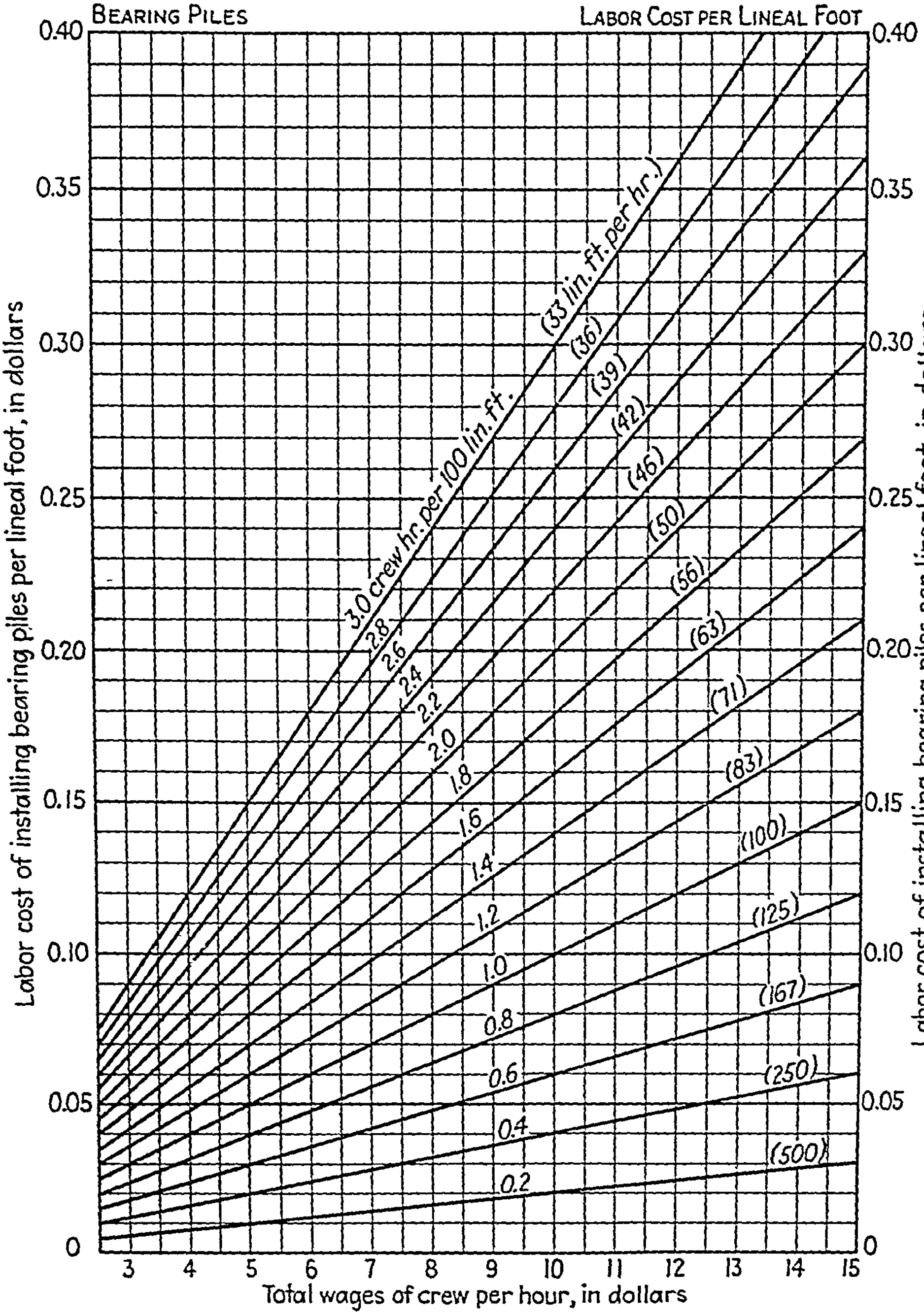

DIAGRAM 4-5.—Labor cost per lineal foot of installing bearing piles.

DIAGRAM 4-6

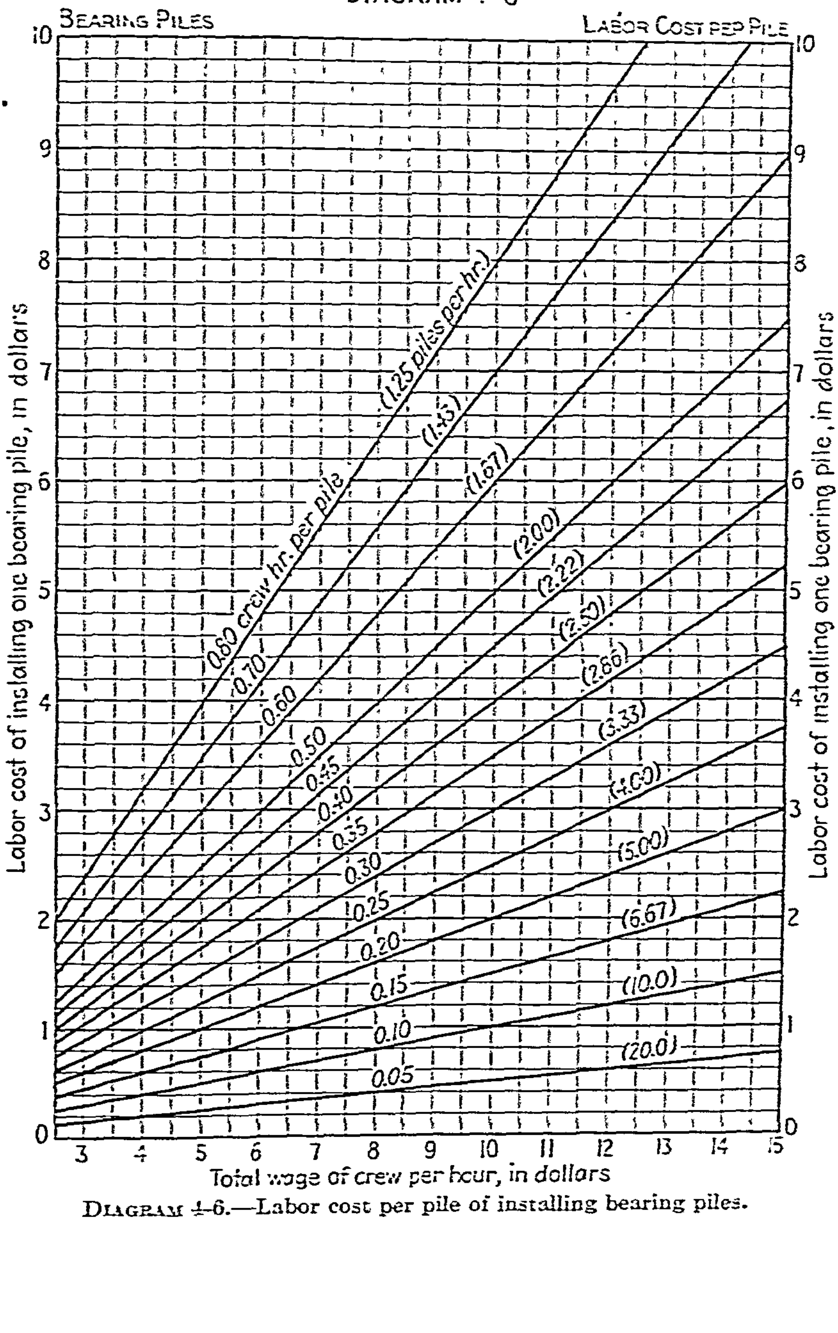

DIAGRAM 4-6.—Labor cost per pile of installing bearing piles.

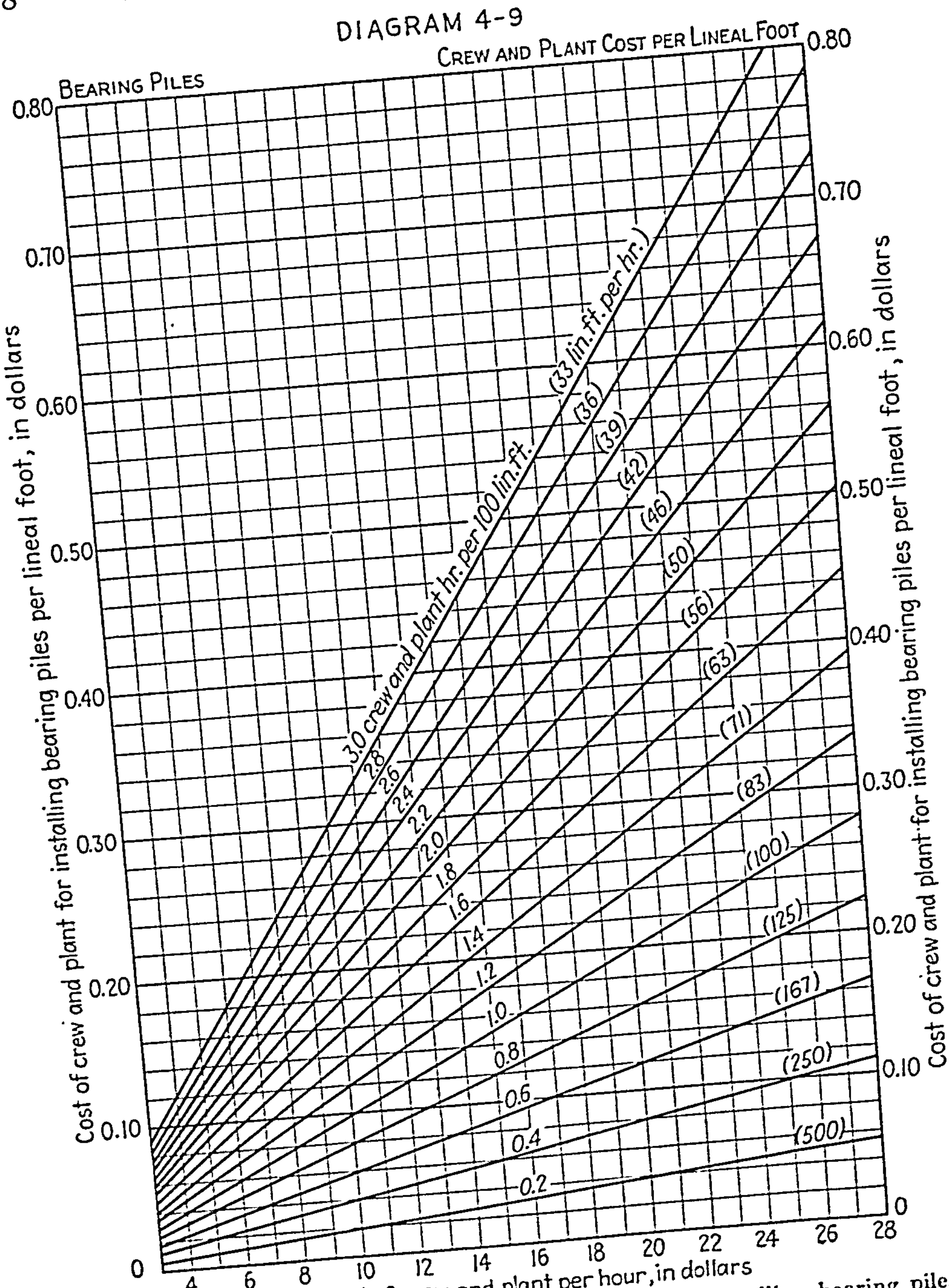

DIAGRAM 4-9.—Crew and plant cost per lineal foot of installing bearing piles

DIAGRAM 4-10

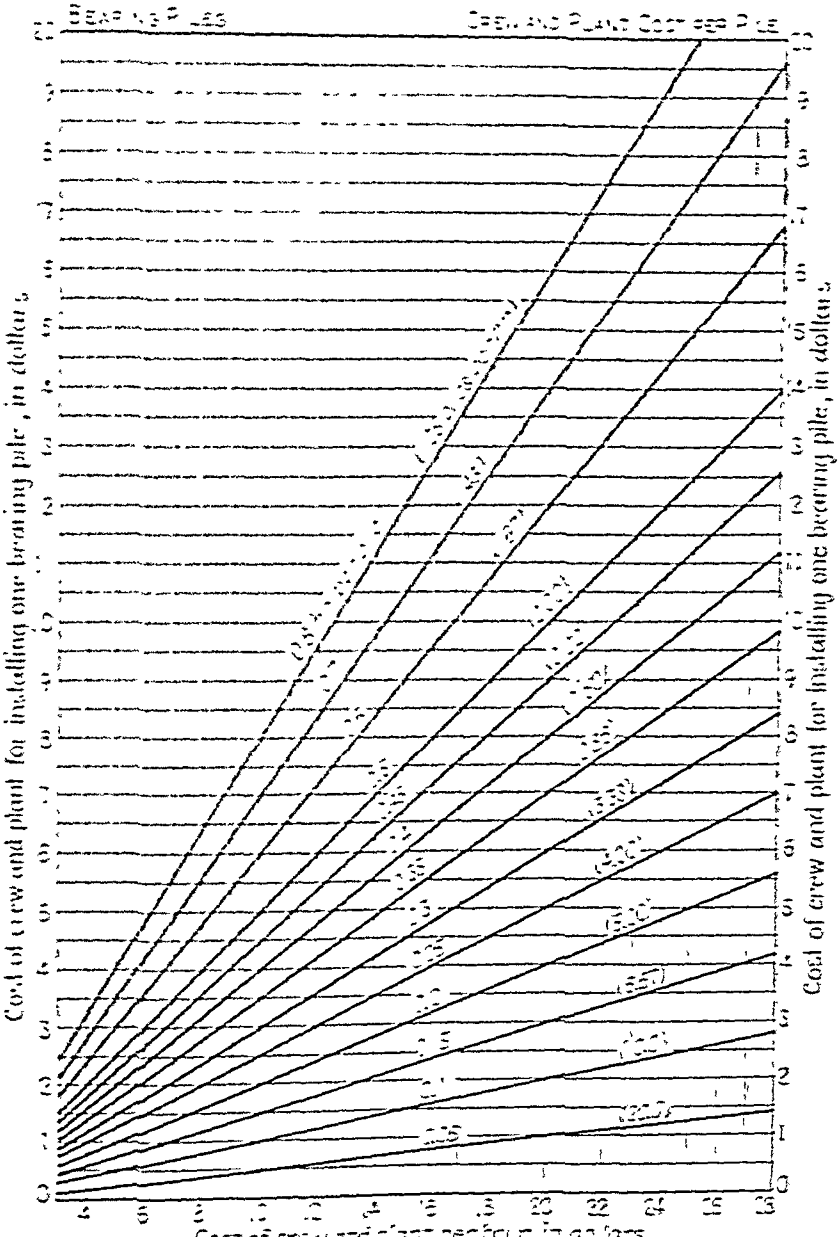

DIAGRAM 4-10.—Crew and plant cost per pile of installing bearing piles.

DIAGRAM 5-1

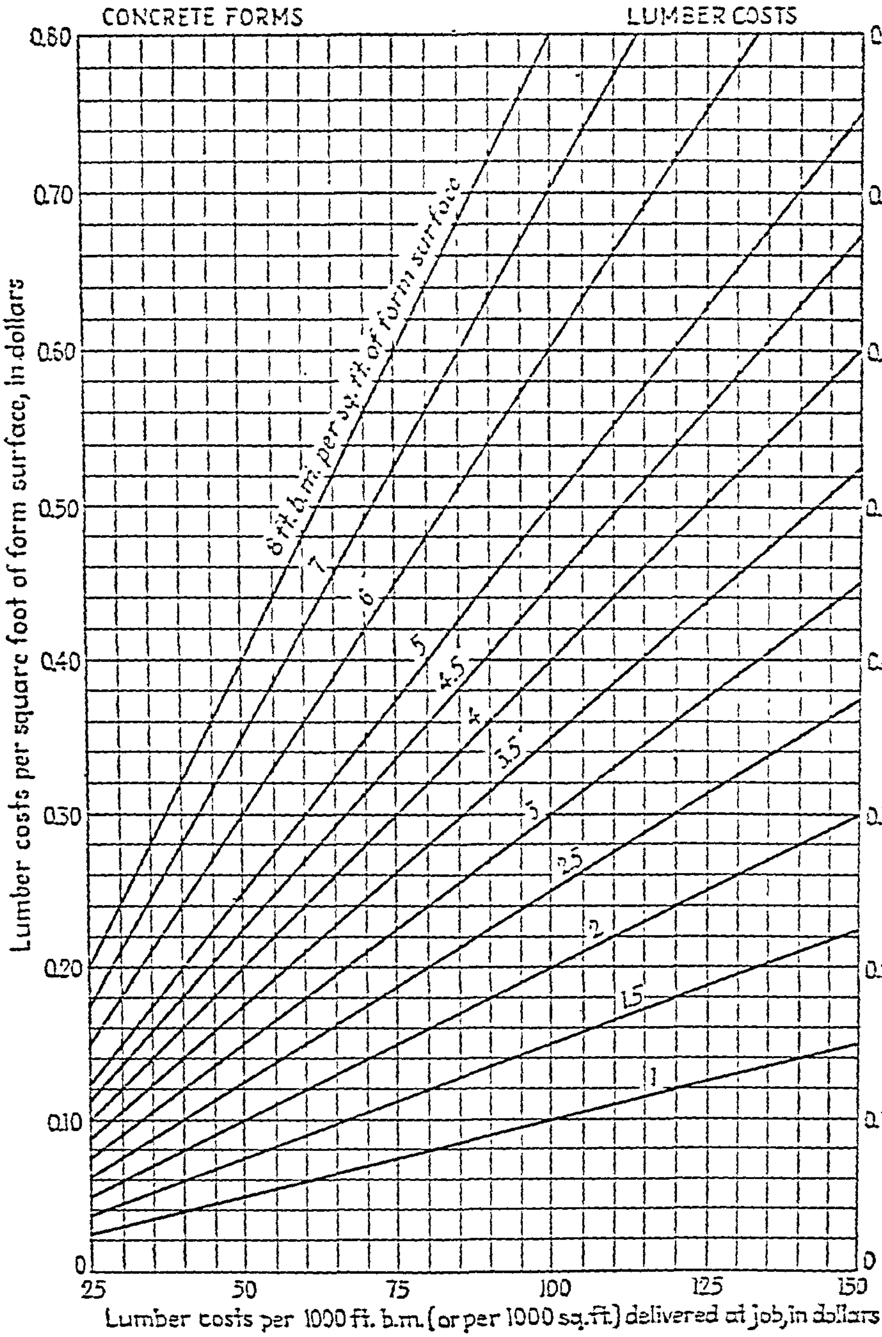

DIAGRAM 5-1.—Lumber costs for forms for concrete.

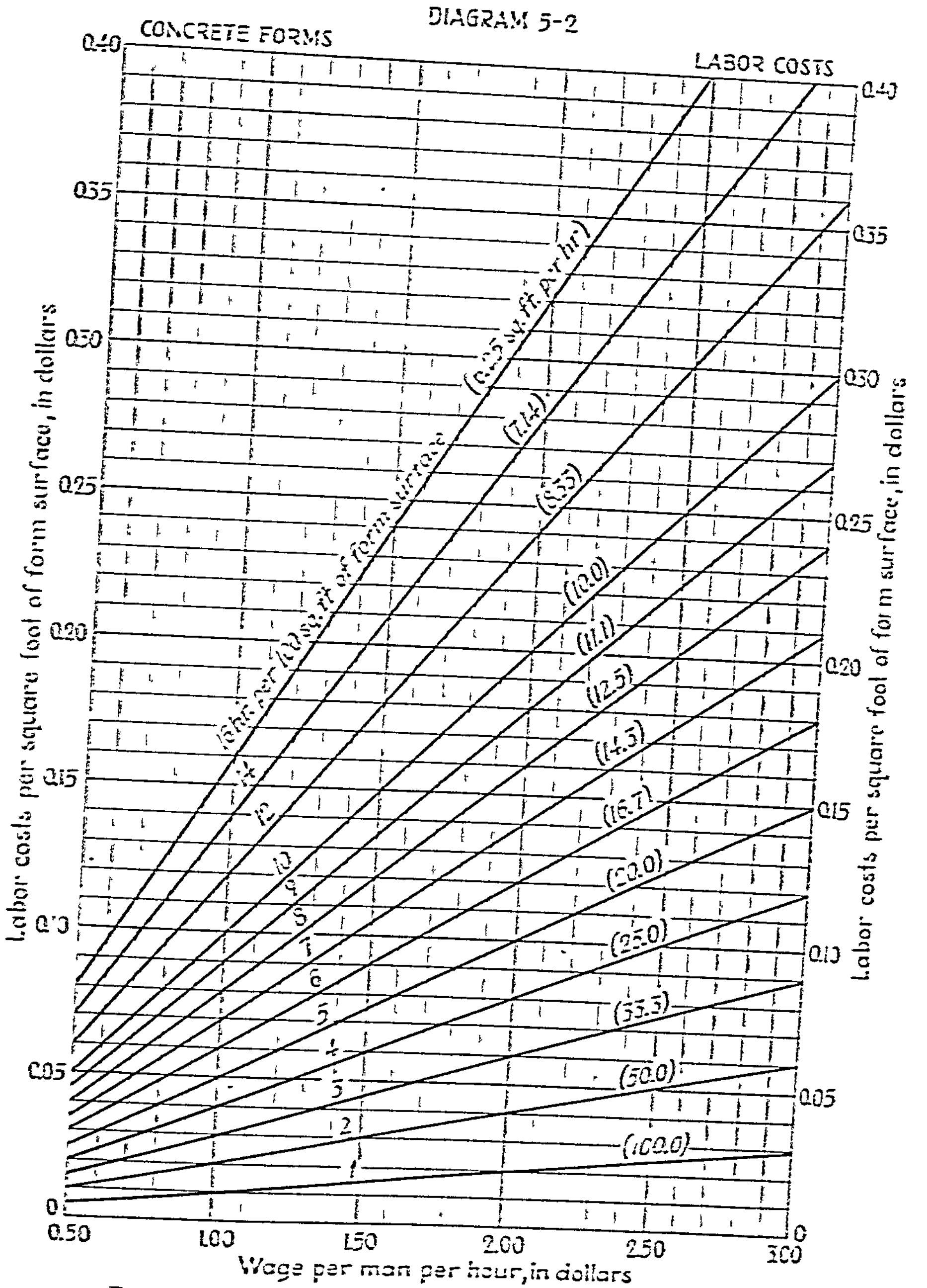

DIAGRAM 5-2.—Labor costs per square foot of form surface.

DIAGRAM 5-3

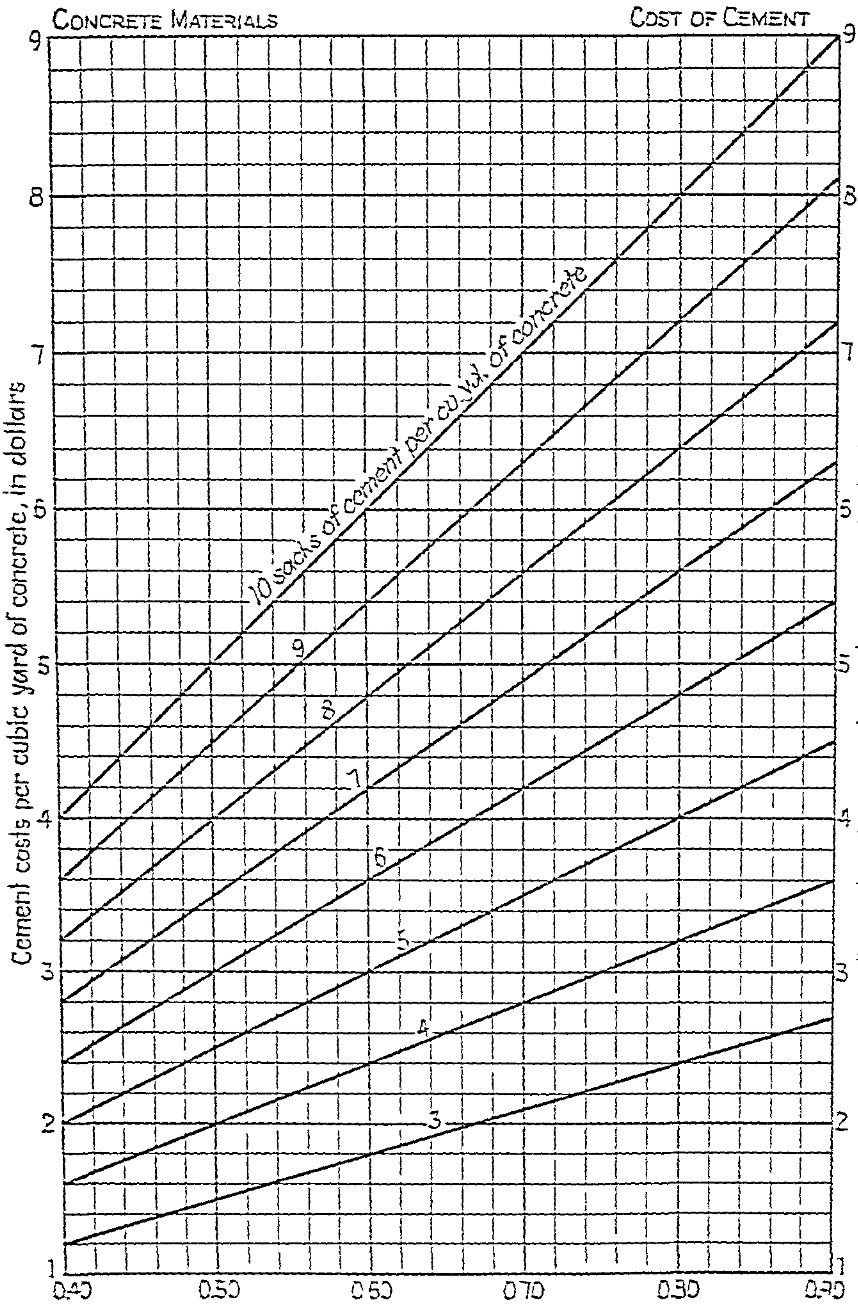

DIAGRAM 5-3.—Cost of cement per cubic yard of concrete.

DIAGRAM 5-4

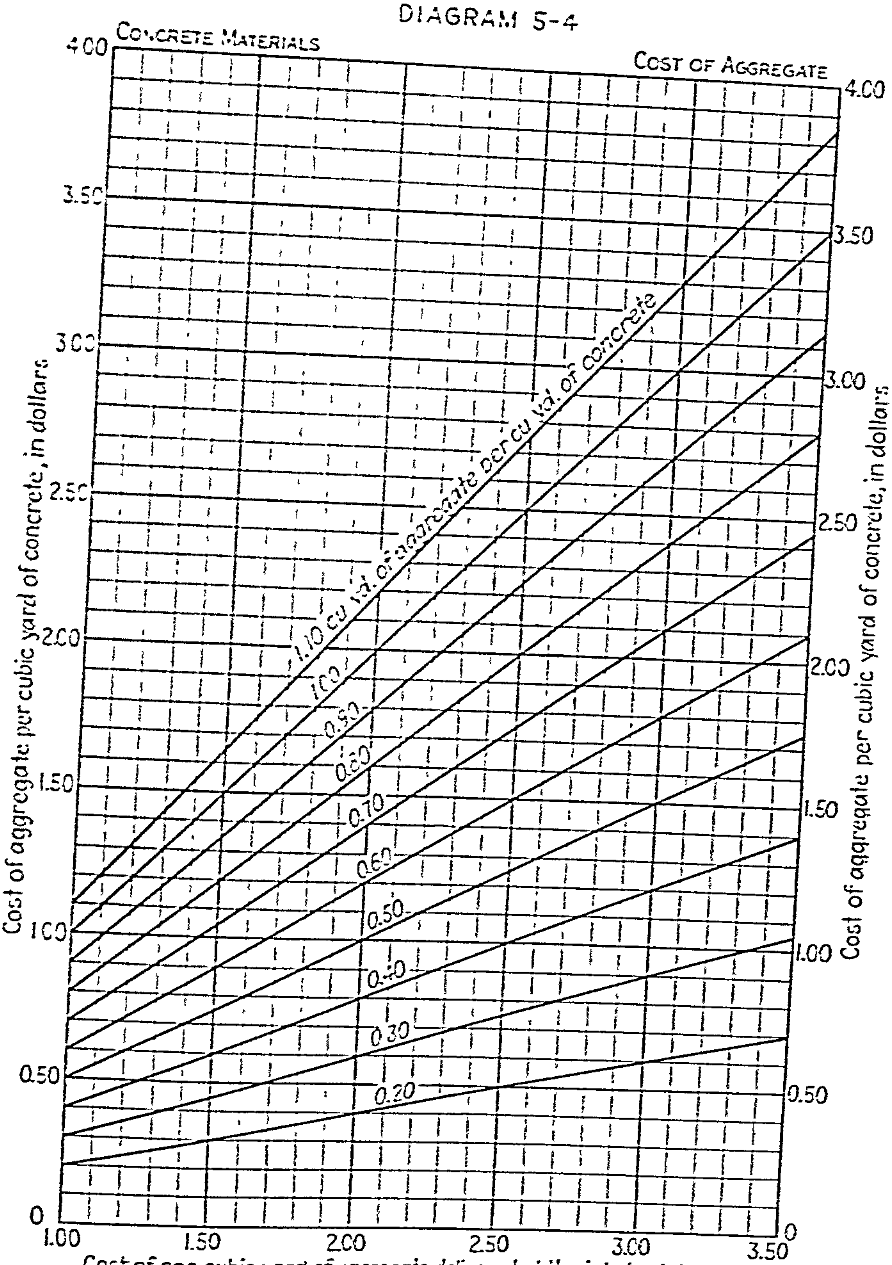

DIAGRAM 5-4.—Cost of aggregate per cubic yard of concrete. Aggregate measured and priced per cubic yard.

DIAGRAM 5-5

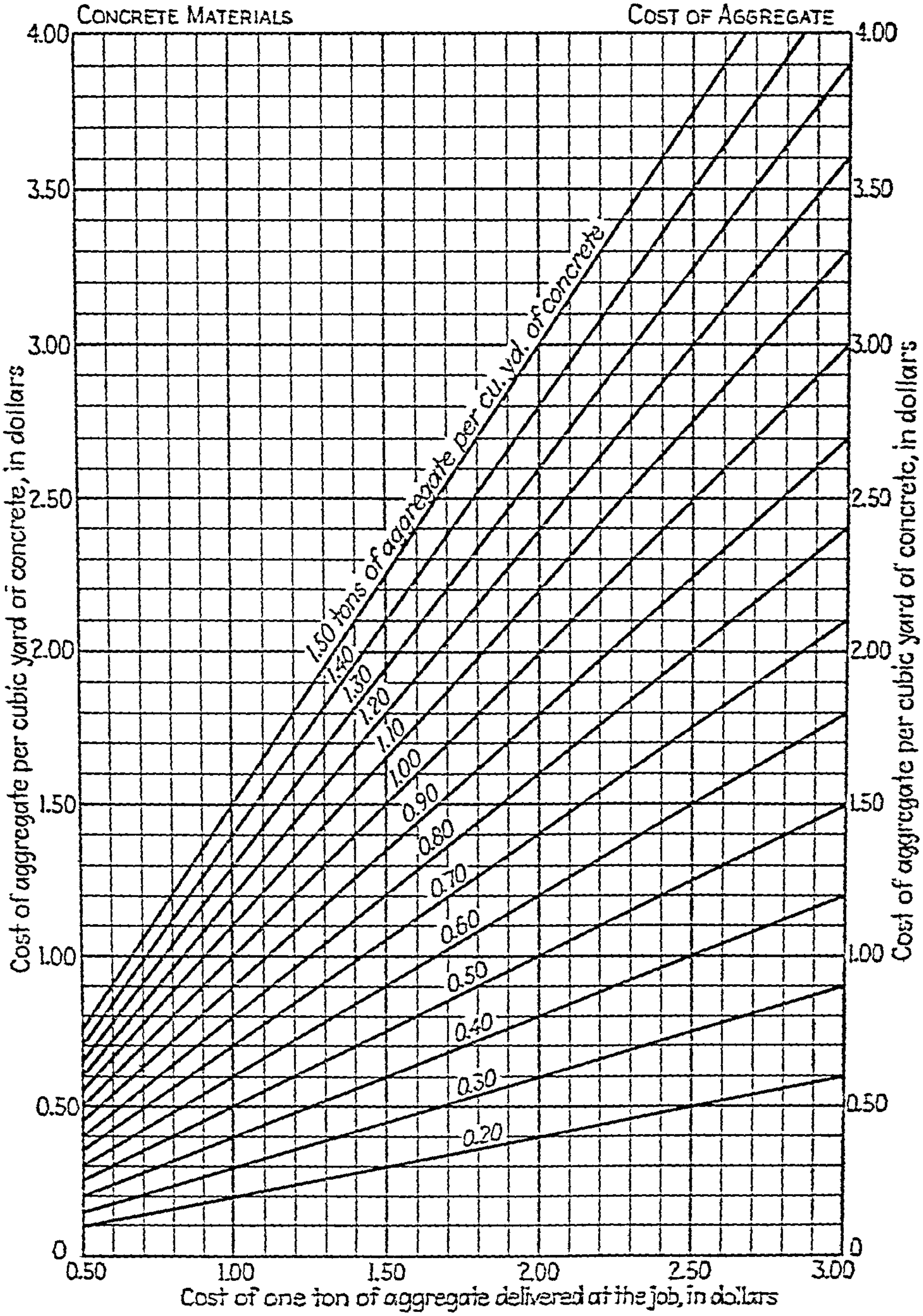

DIAGRAM 5-5.—Cost of aggregate per cubic yard of concrete. Aggregate measured and priced per ton.

DIAGRAM 5-6

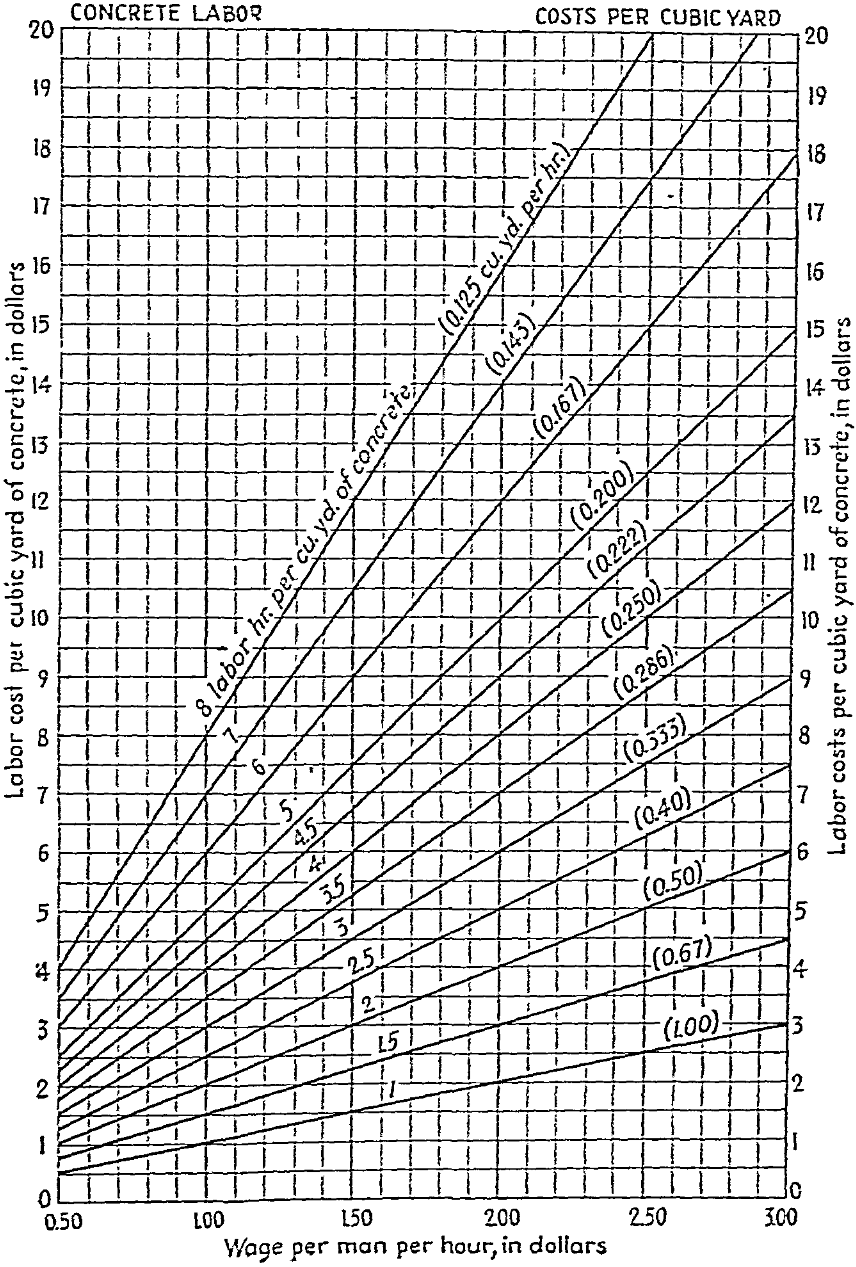

DIAGRAM 5-6.—Labor cost per cubic yard of concrete.

DIAGRAM 5-10

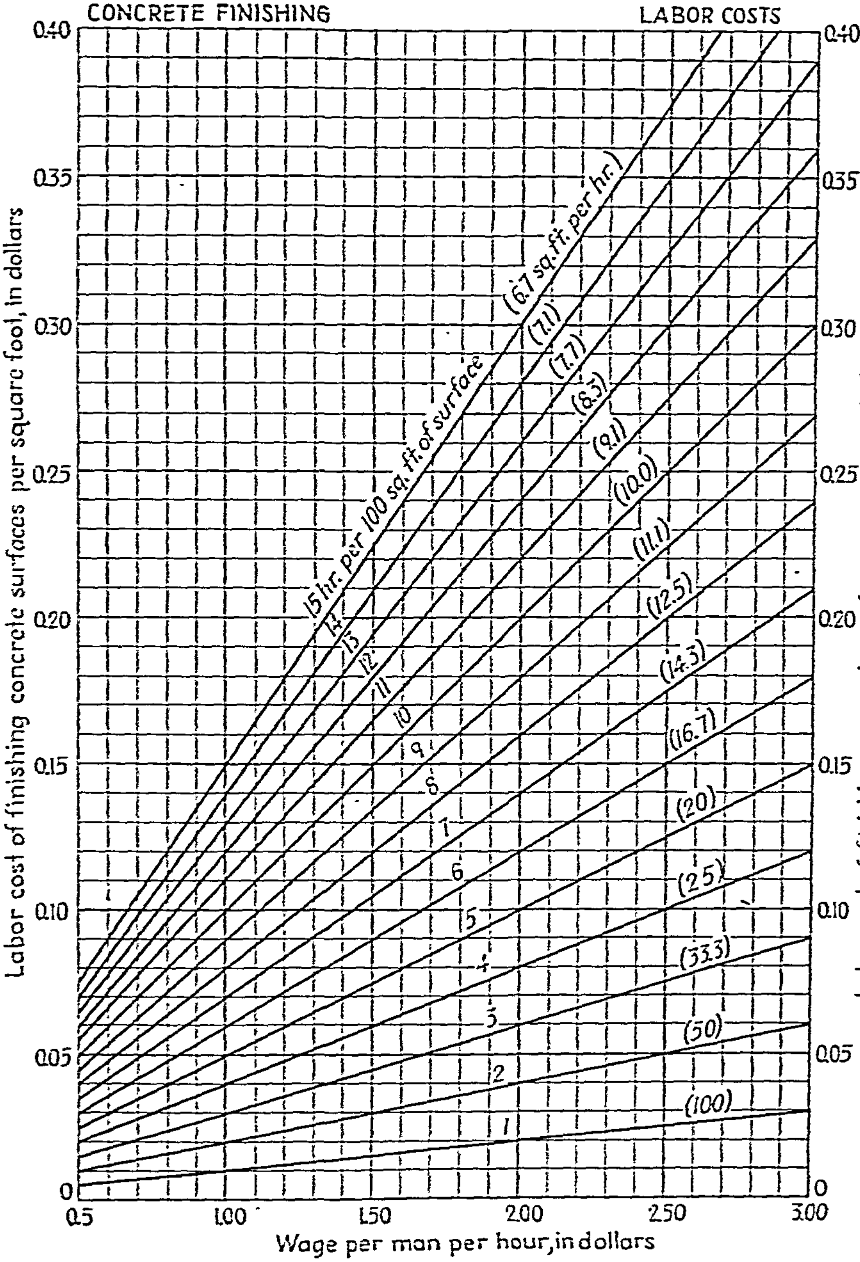

DIAGRAM 5-10.—Labor costs of finishing concrete surfaces.

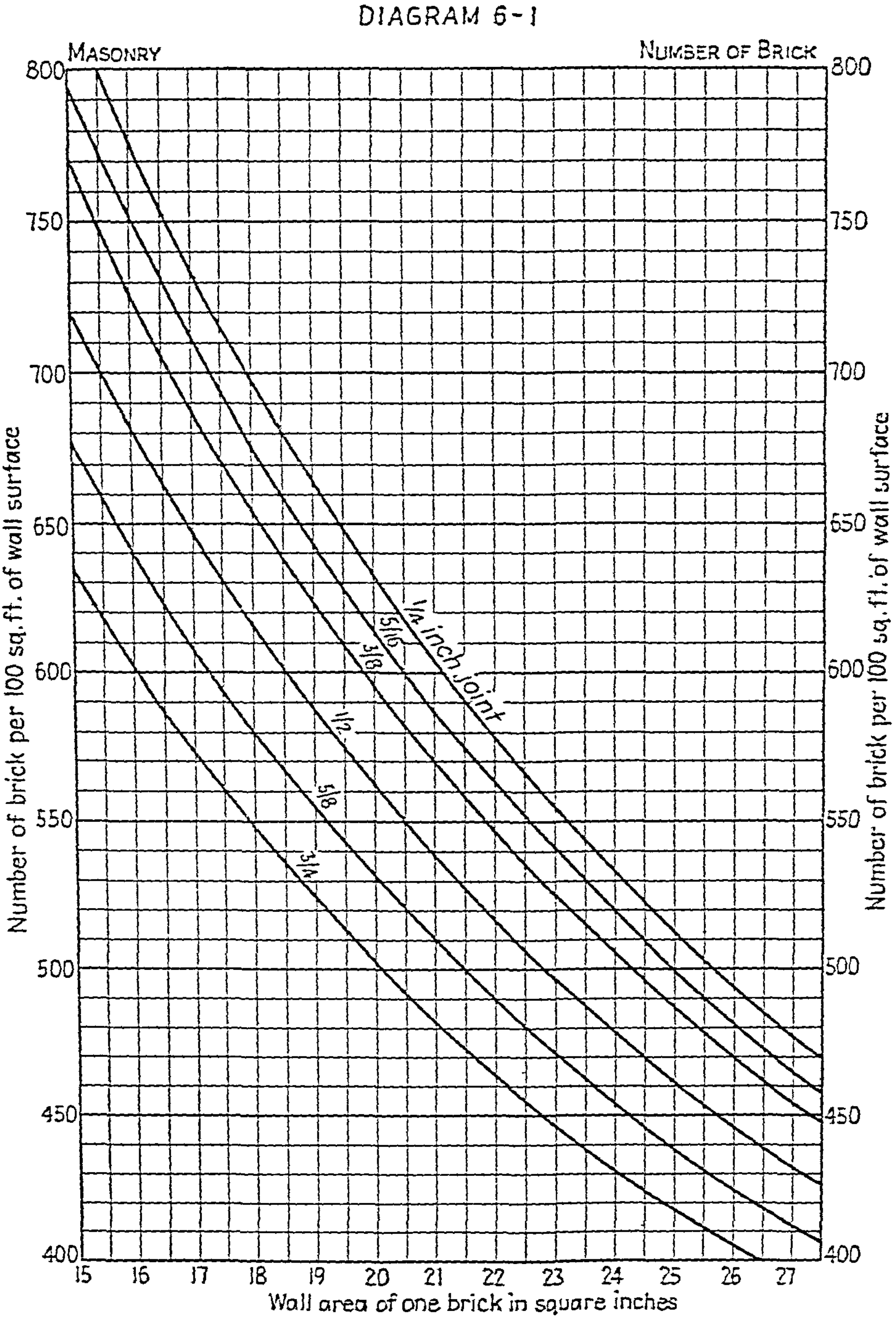

DIAGRAM 6-1.—Number of brick per 100 sq. ft. of wall surface. Varying thicknesses of joints.

DIAGRAM 6-2

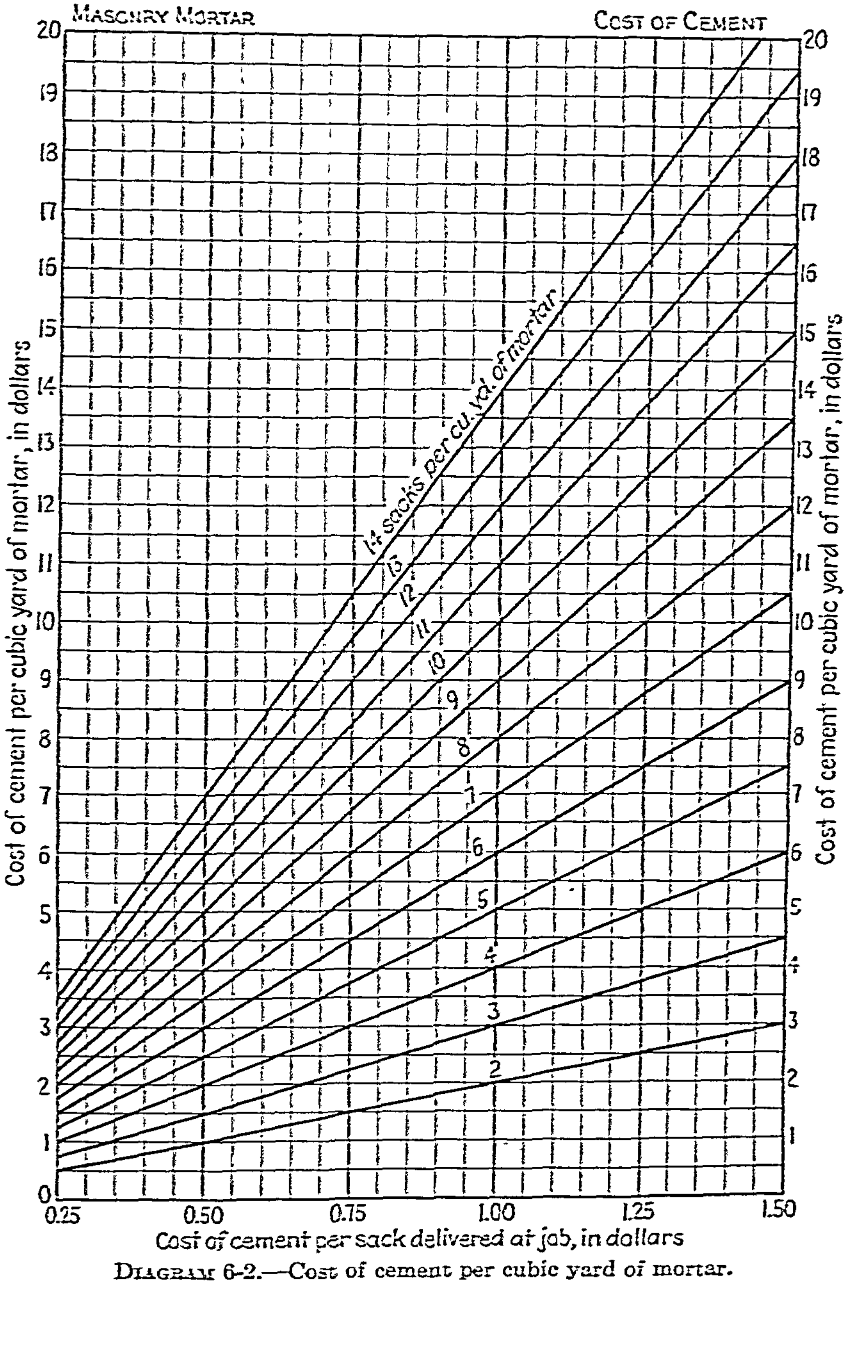

DIAGRAM 6-2.—Cost of cement per cubic yard of mortar.

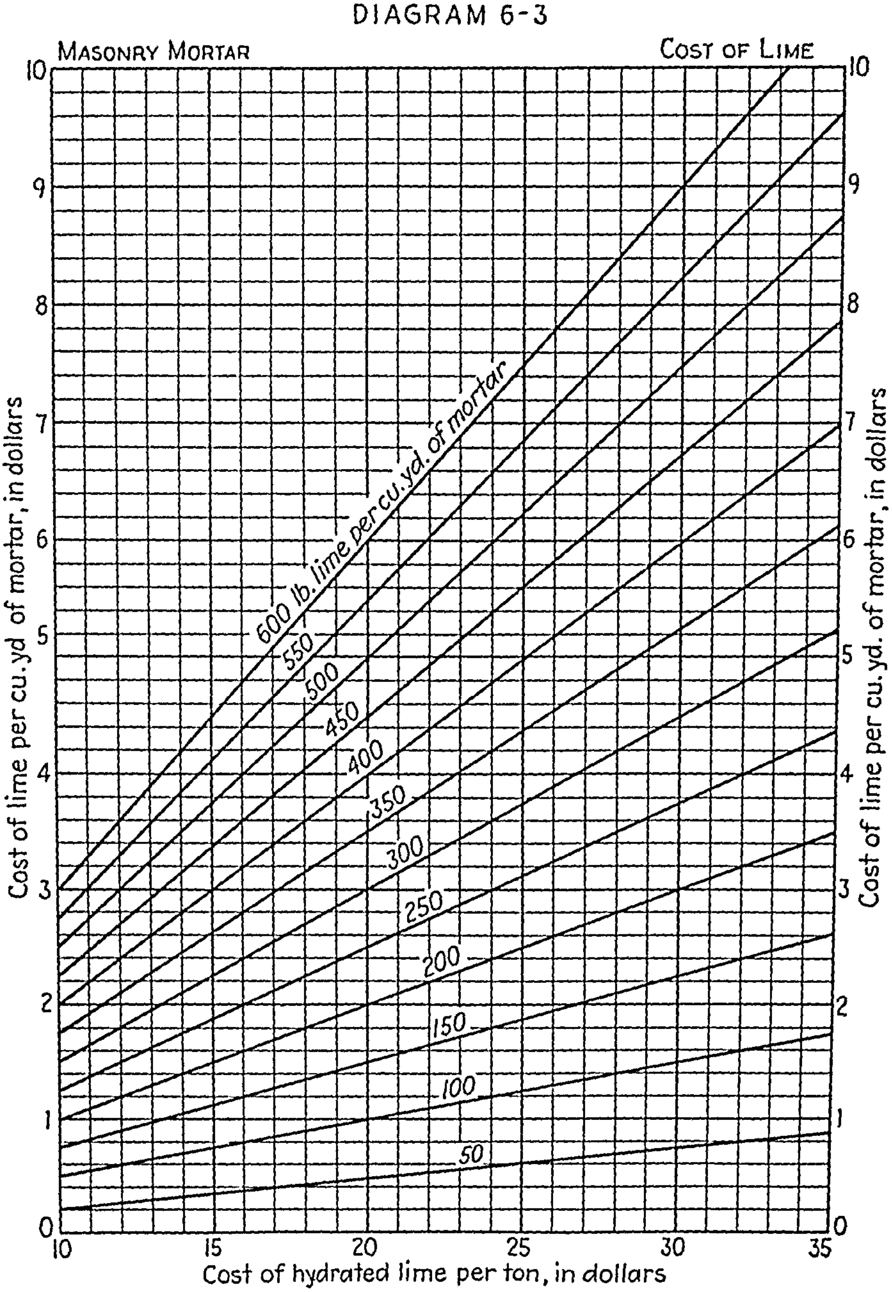

DIAGRAM 6-3.—Cost of lime per cubic yard of mortar.

DIAGRAM 6-4

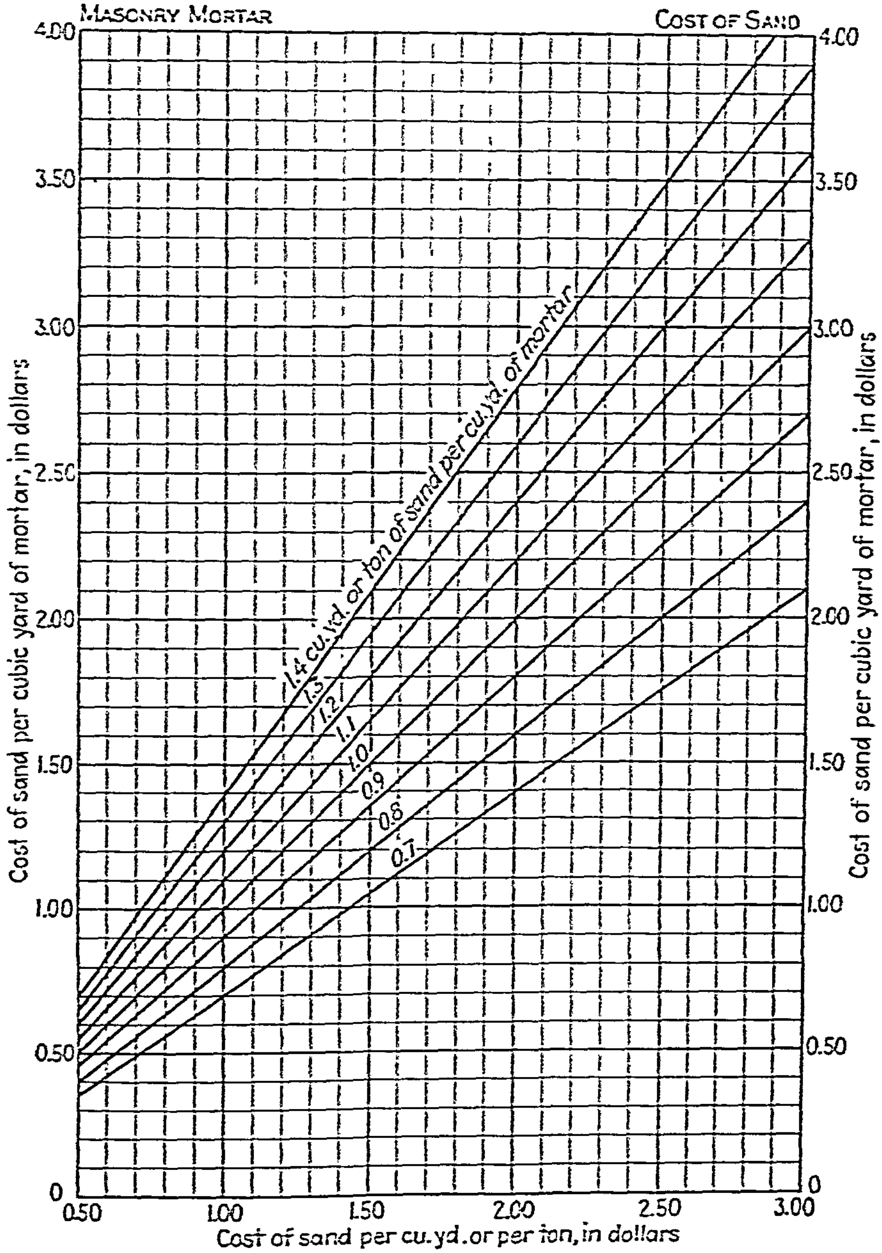

DIAGRAM 6-4.—Cost of sand per cubic yard of mortar.

DIAGRAM 6-5

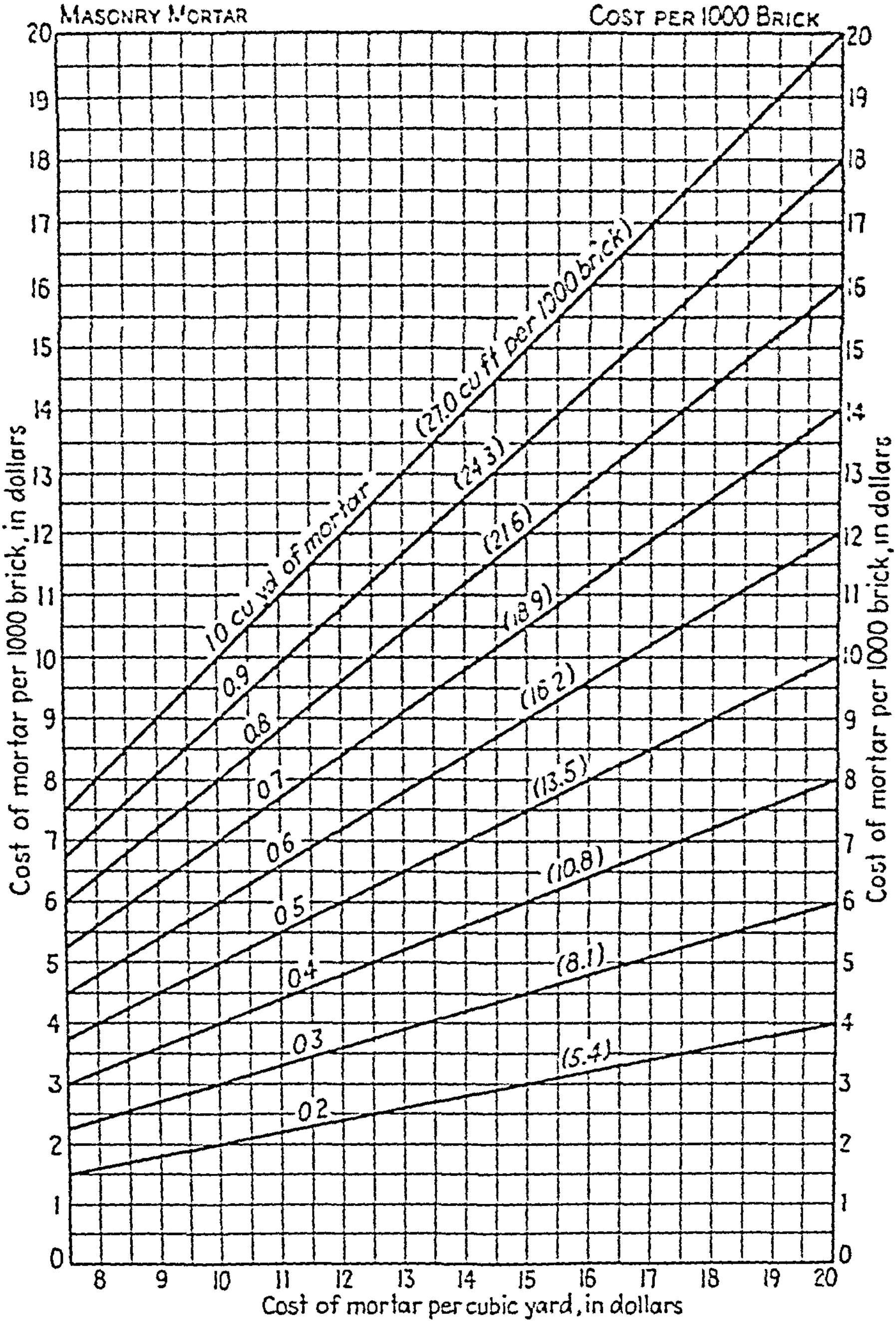

DIAGRAM 6-5.—Cost of mortar per 1000 brick for brick masonry.

DIAGRAM 6-6

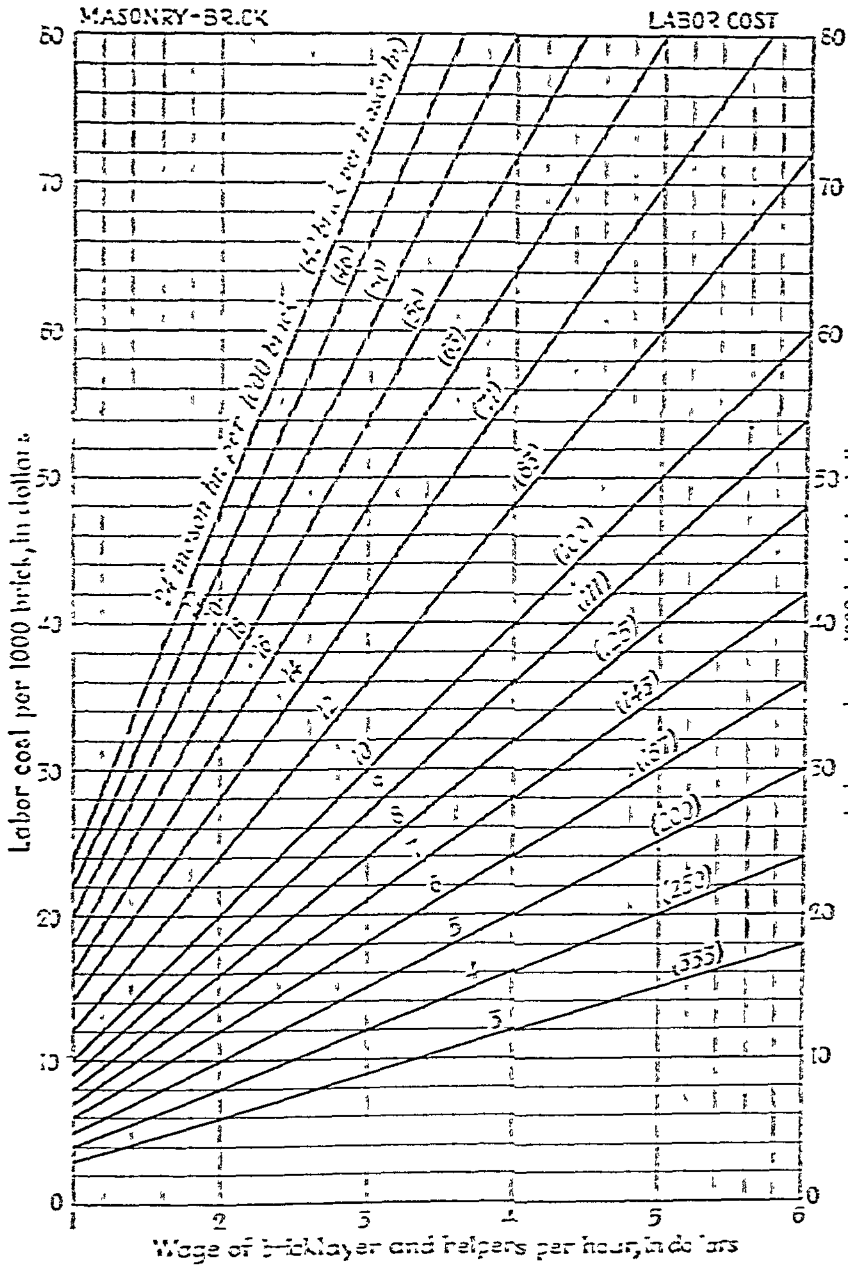

DIAGRAM 6-6.—Labor cost of laying brick masonry per 1000 brick

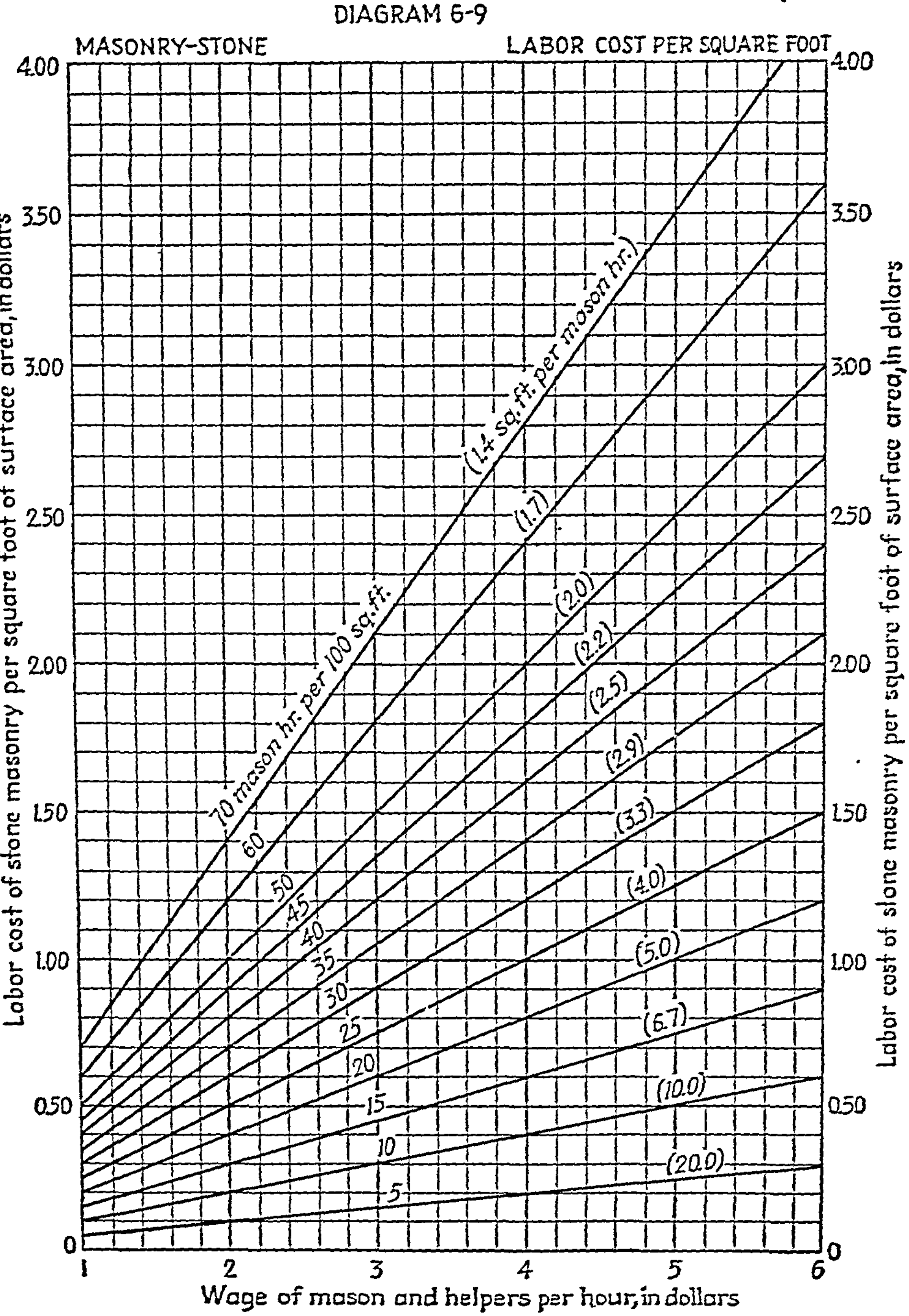

DIAGRAM 6-9.—Labor cost per square foot of surface area for stone masonry.

DIAGRAM 6-10

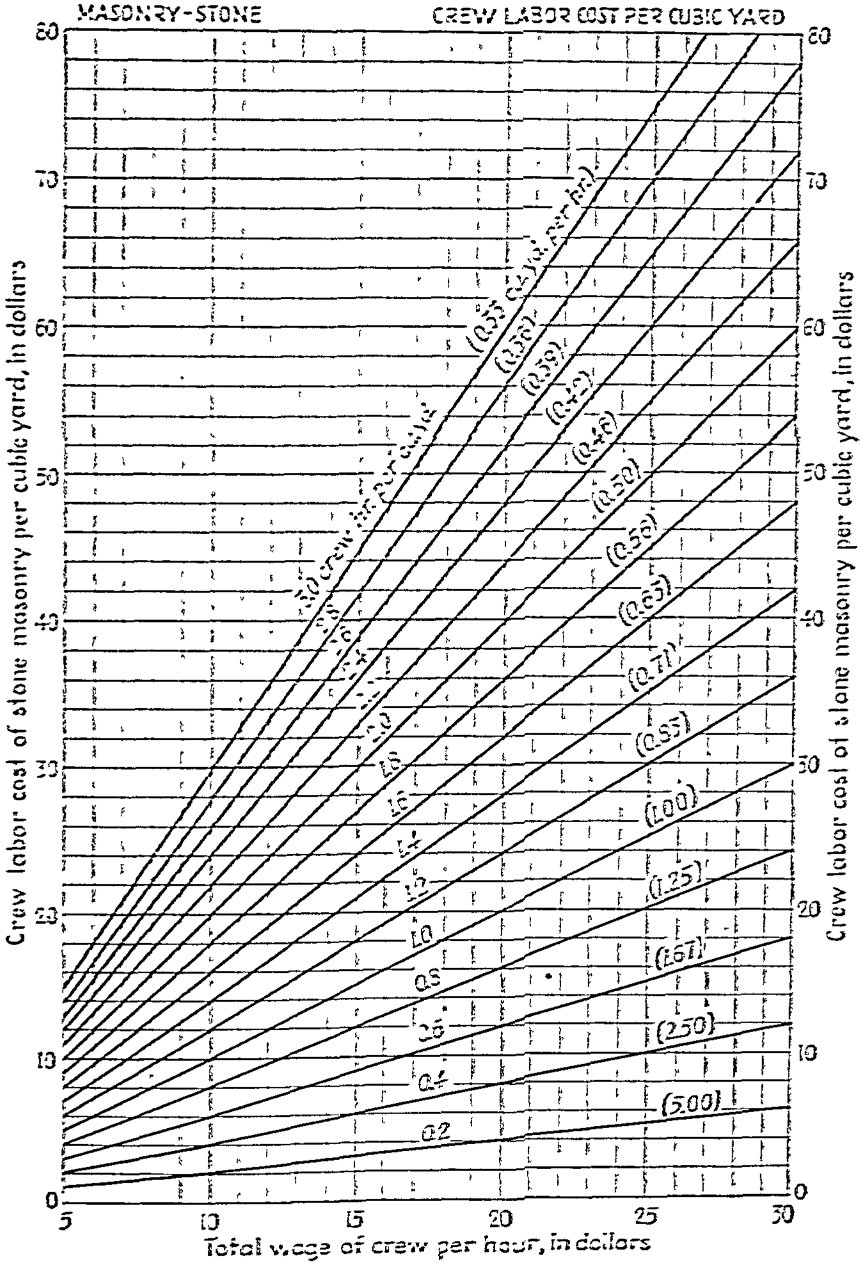

Diagram 6-10.—Crew labor cost per cubic yard for laying stone masonry.

DIAGRAM 7-1

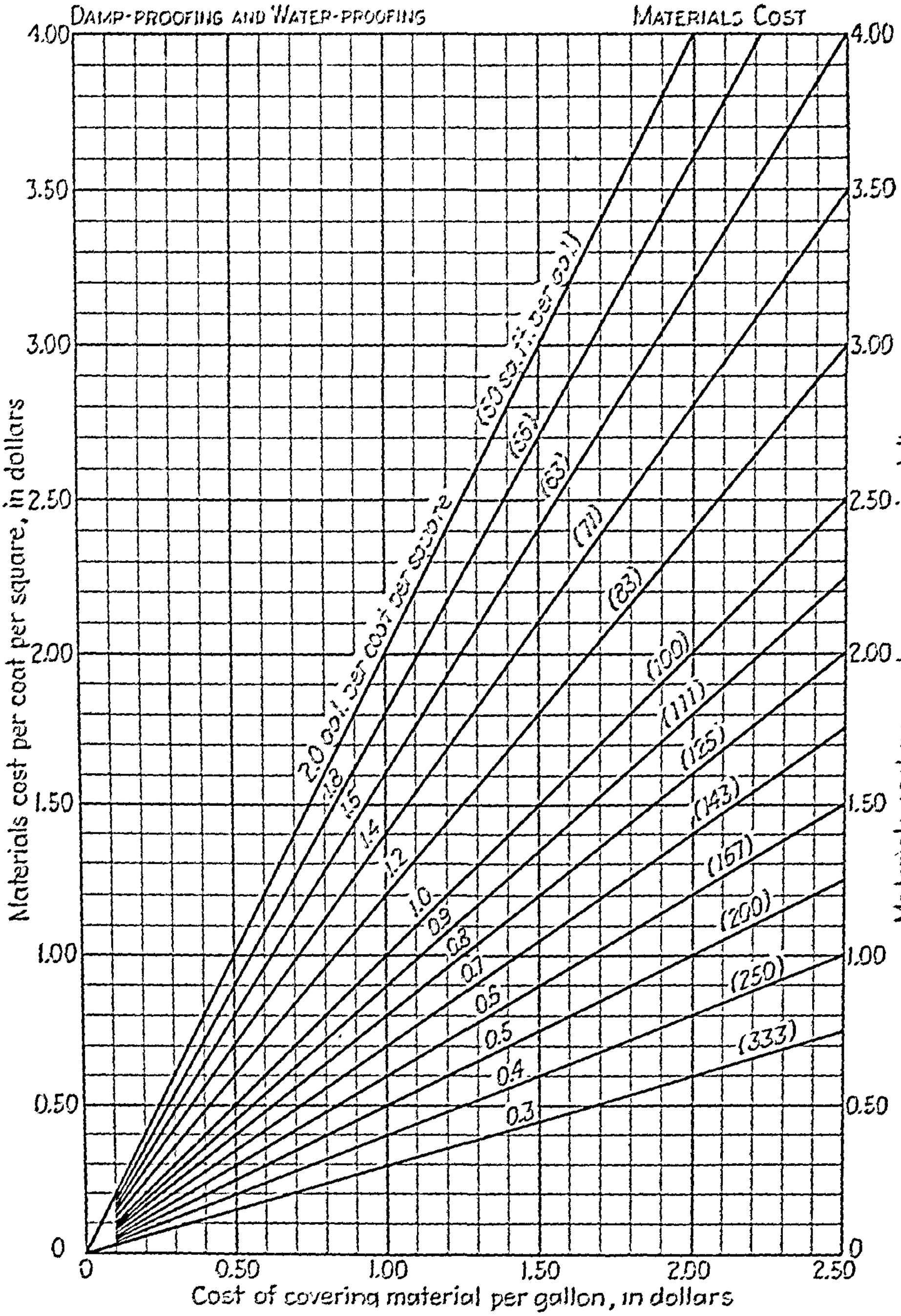

DIAGRAM 7-1.—Materials cost per coat per square for dampproofing and waterproofing. Materials sold by the gallon.

DIAGRAM 7-2

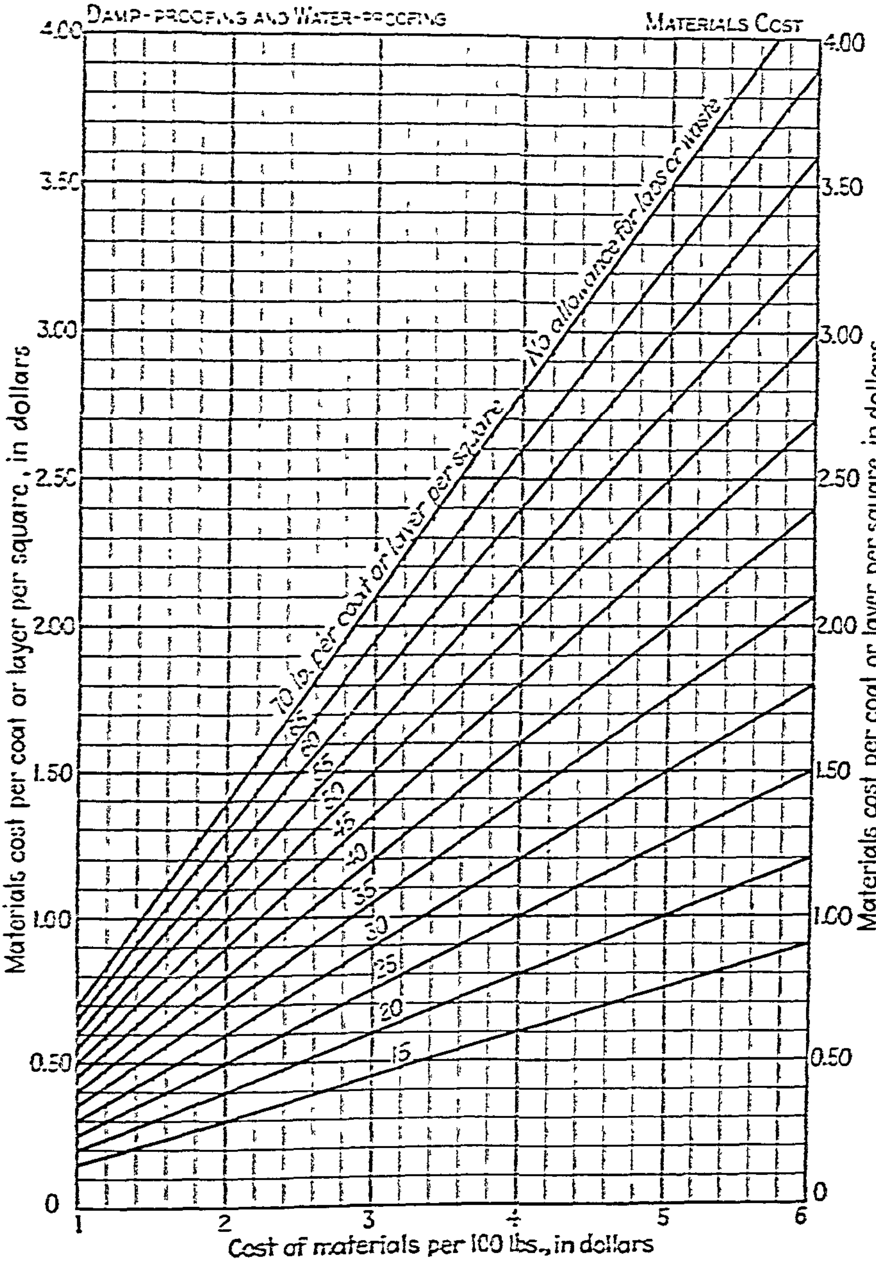

DIAGRAM 7-2.—Materials cost per square for dampproofing and waterproofing with no allowance for laps or waste. Materials sold by the 100 lb.

DIAGRAM 7-3

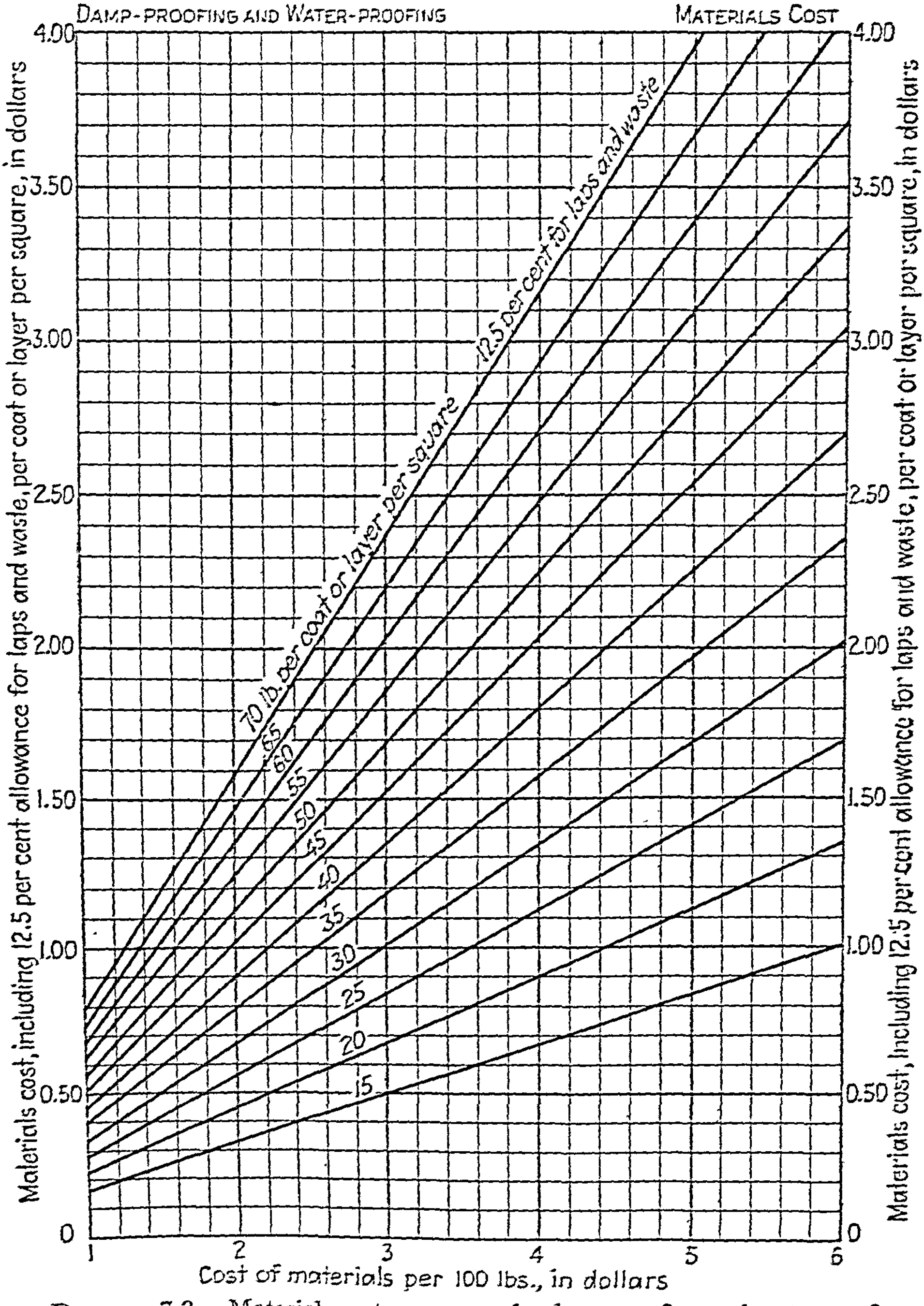

DIAGRAM 7-3.—Materials cost per square for dampproofing and waterproofing, with an allowance of 12.5 per cent for laps and waste. Materials sold by the 100 lbs.

DIAGRAM 7-4

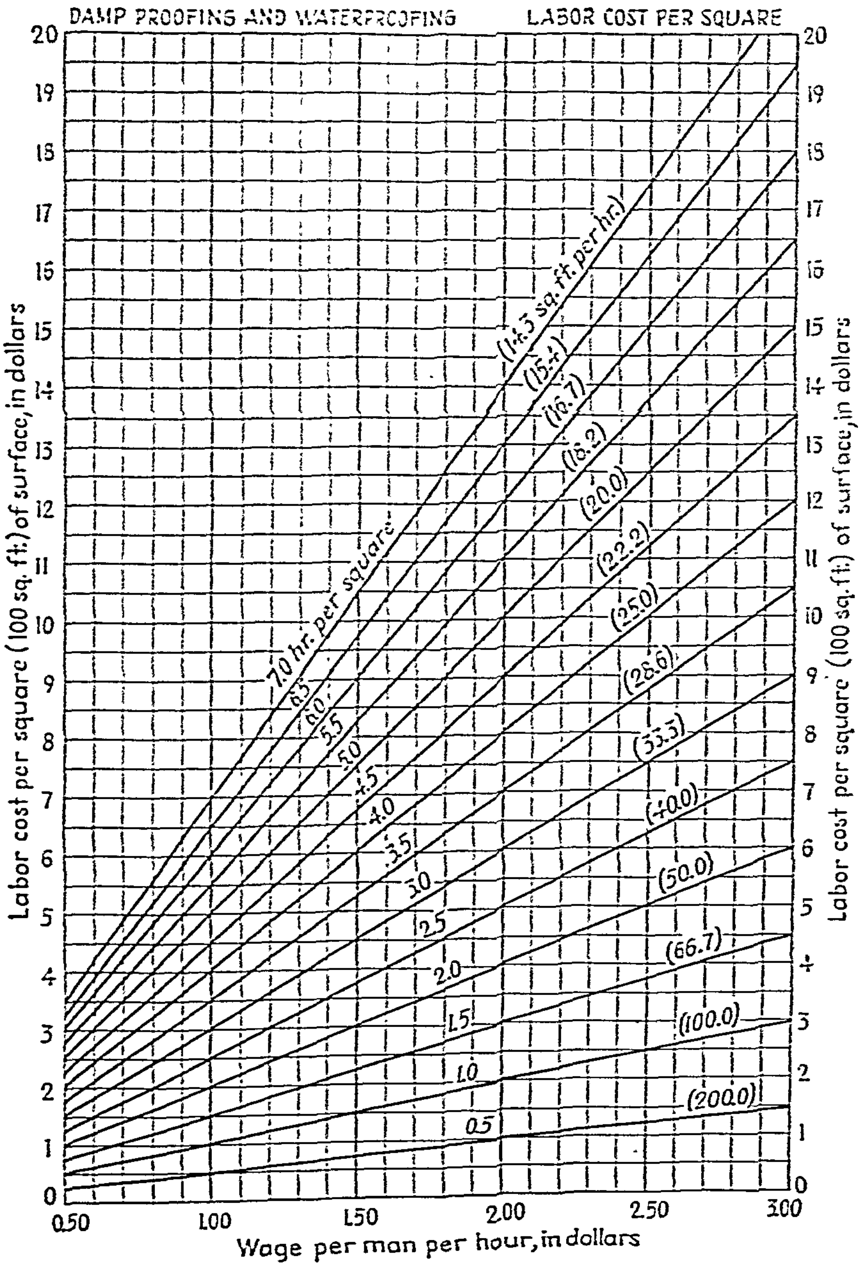

DIAGRAM 7-4.—Labor costs per square of 100 sq. ft. of applying dampproofing and waterproofing materials.

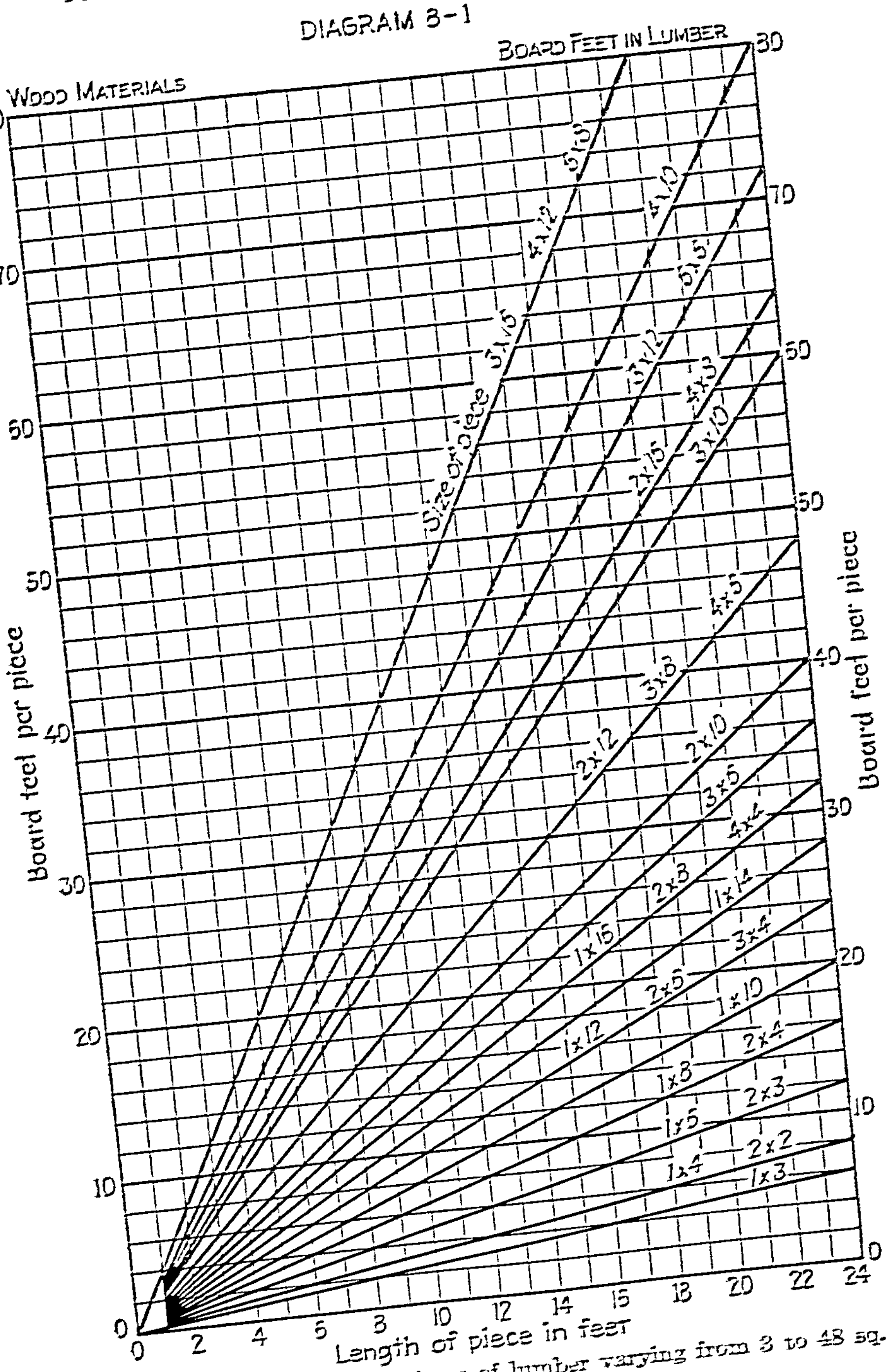

DIAGRAM 8-1.—Board feet in pieces of lumber varying from 3 to 48 sq. in. in cross-sectional area.

DIAGRAM 8-2

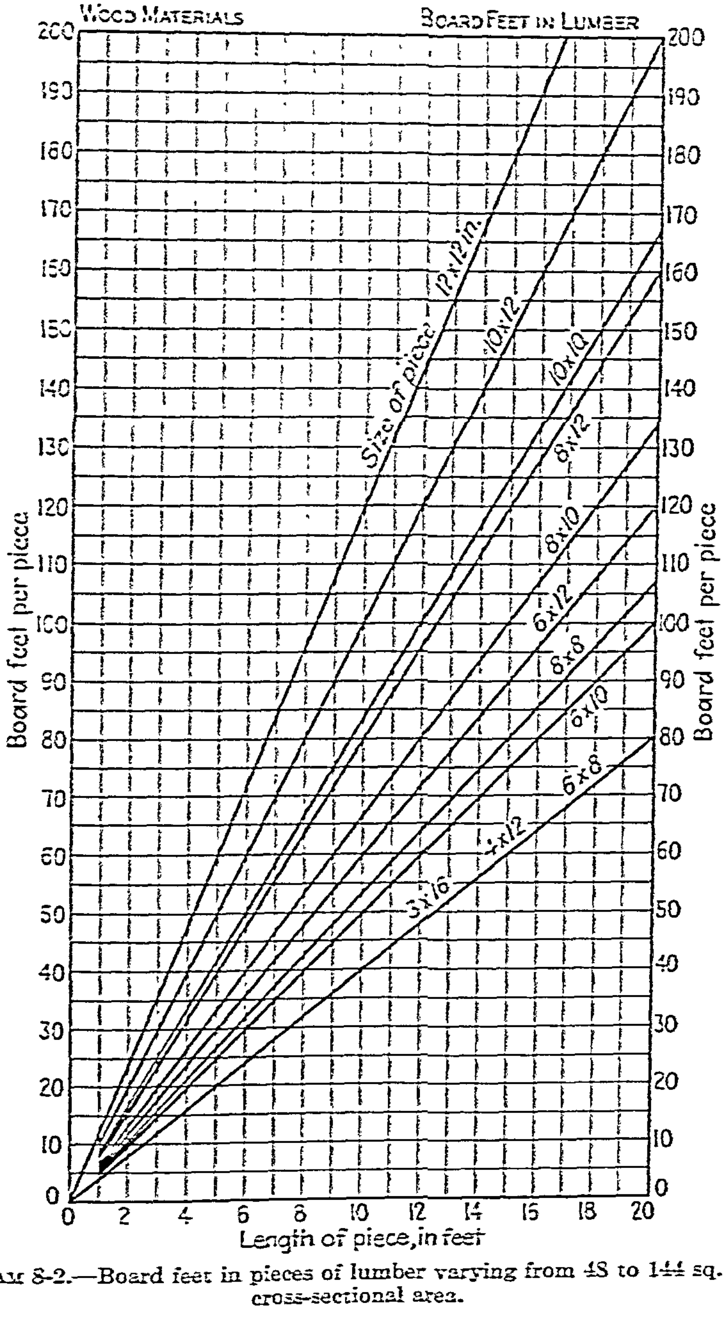

DIAGRAM 8-2.—Board feet in pieces of lumber varying from 48 to 144 sq. in. in cross-sectional area.

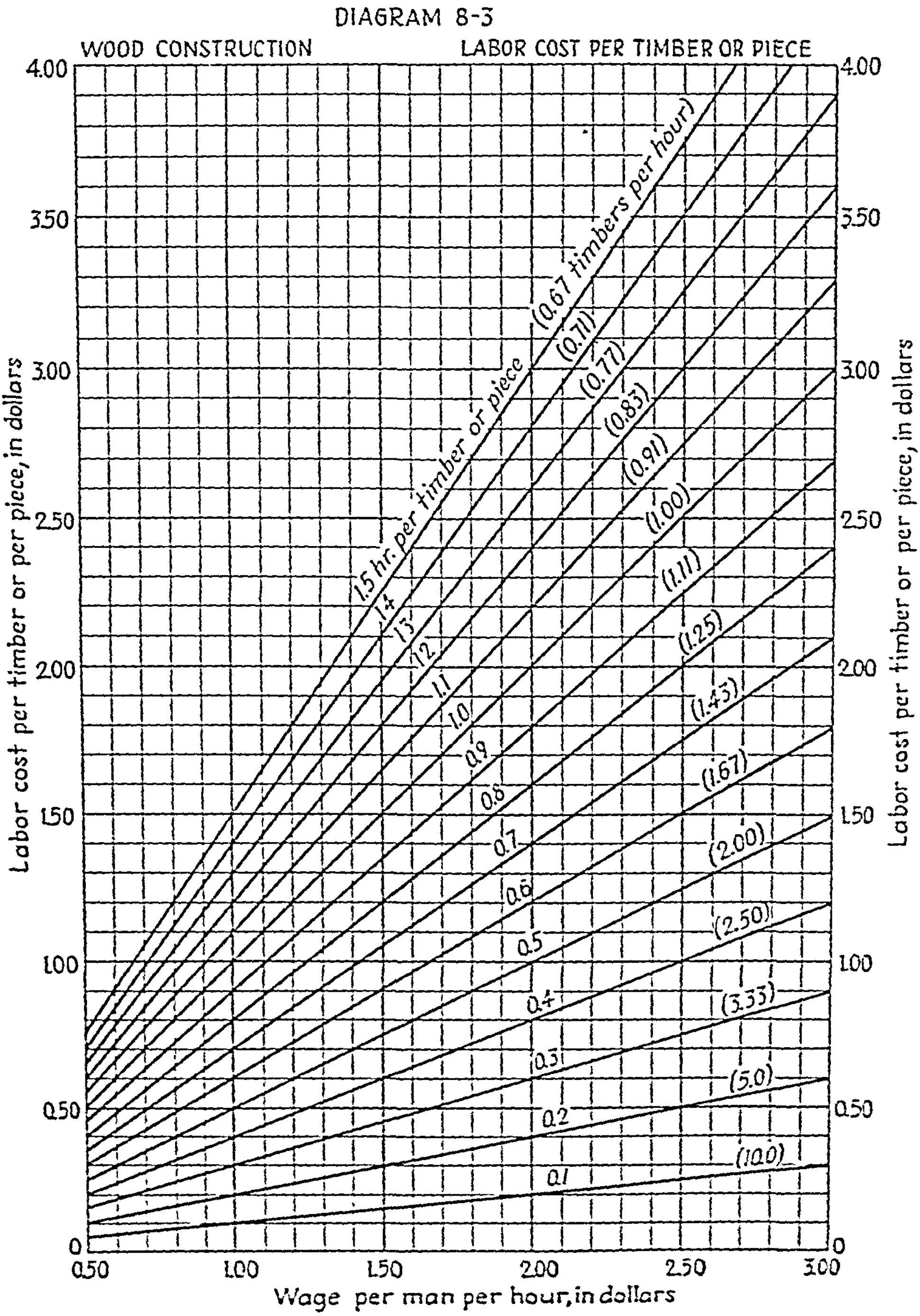

DIAGRAM 8-3.—Labor cost per timber or per piece in wood construction.

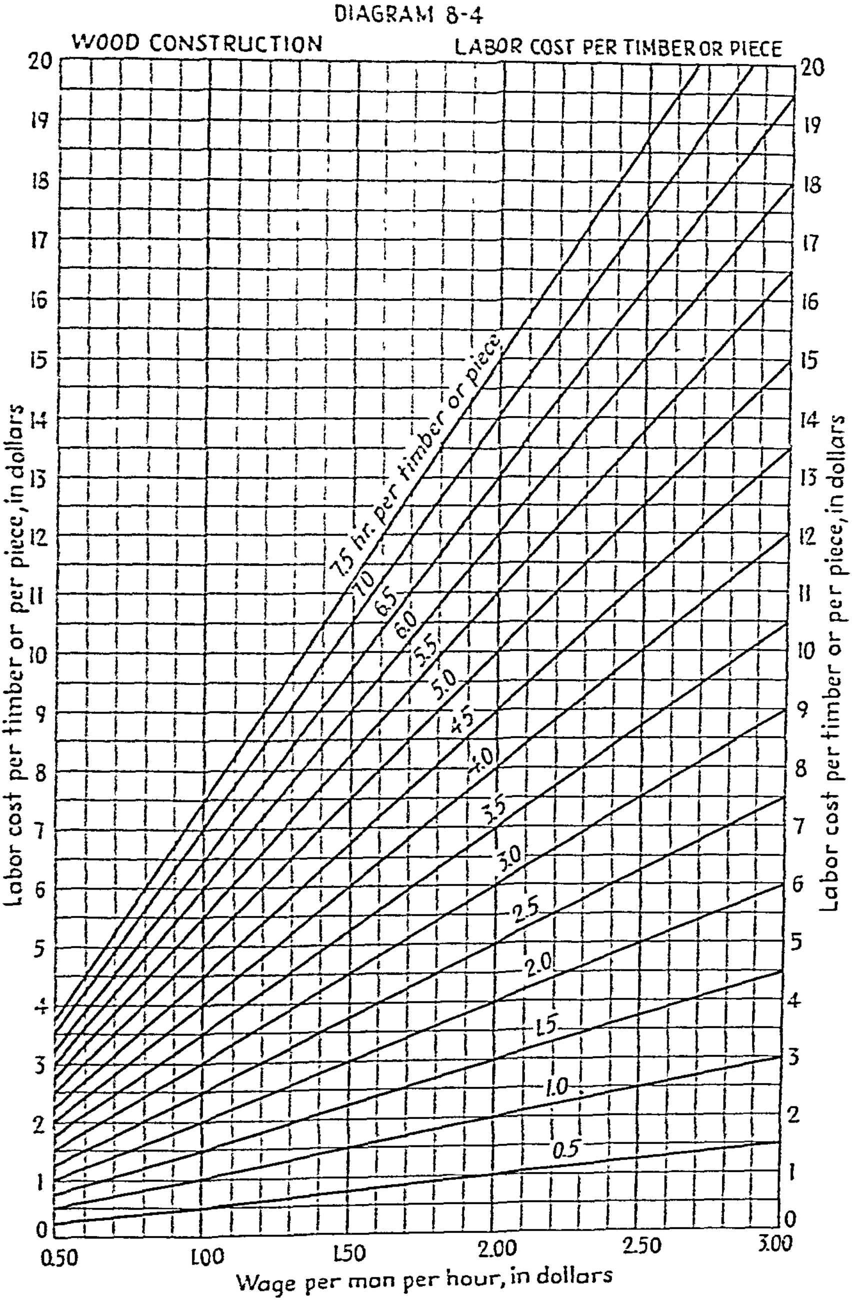

DIAGRAM 8-4.—Labor cost per timber or per piece in wood construction.

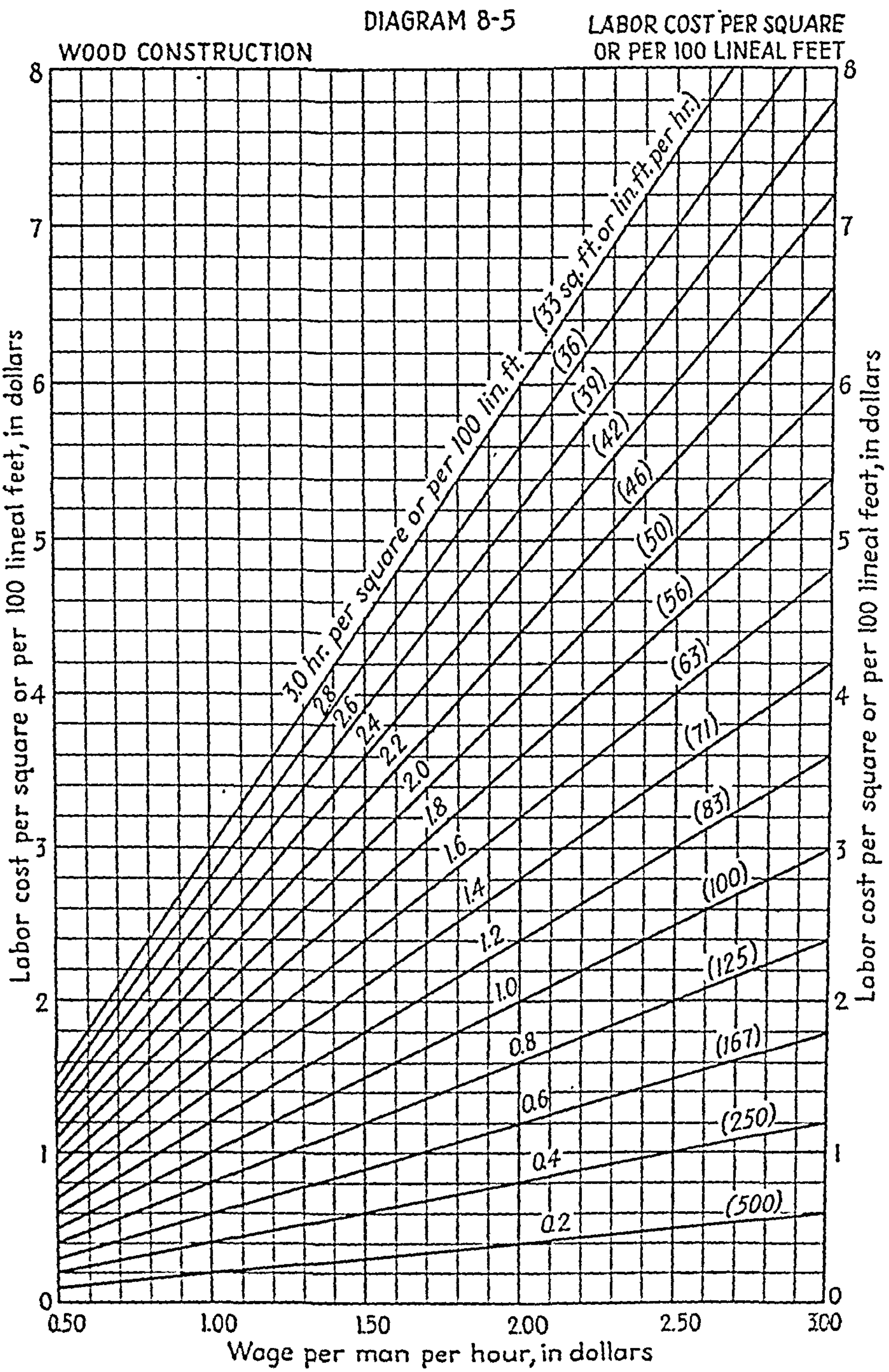

DIAGRAM 8-5.—Labor cost of wood construction per 100 lineal ft. or per square of 100 sq. ft.

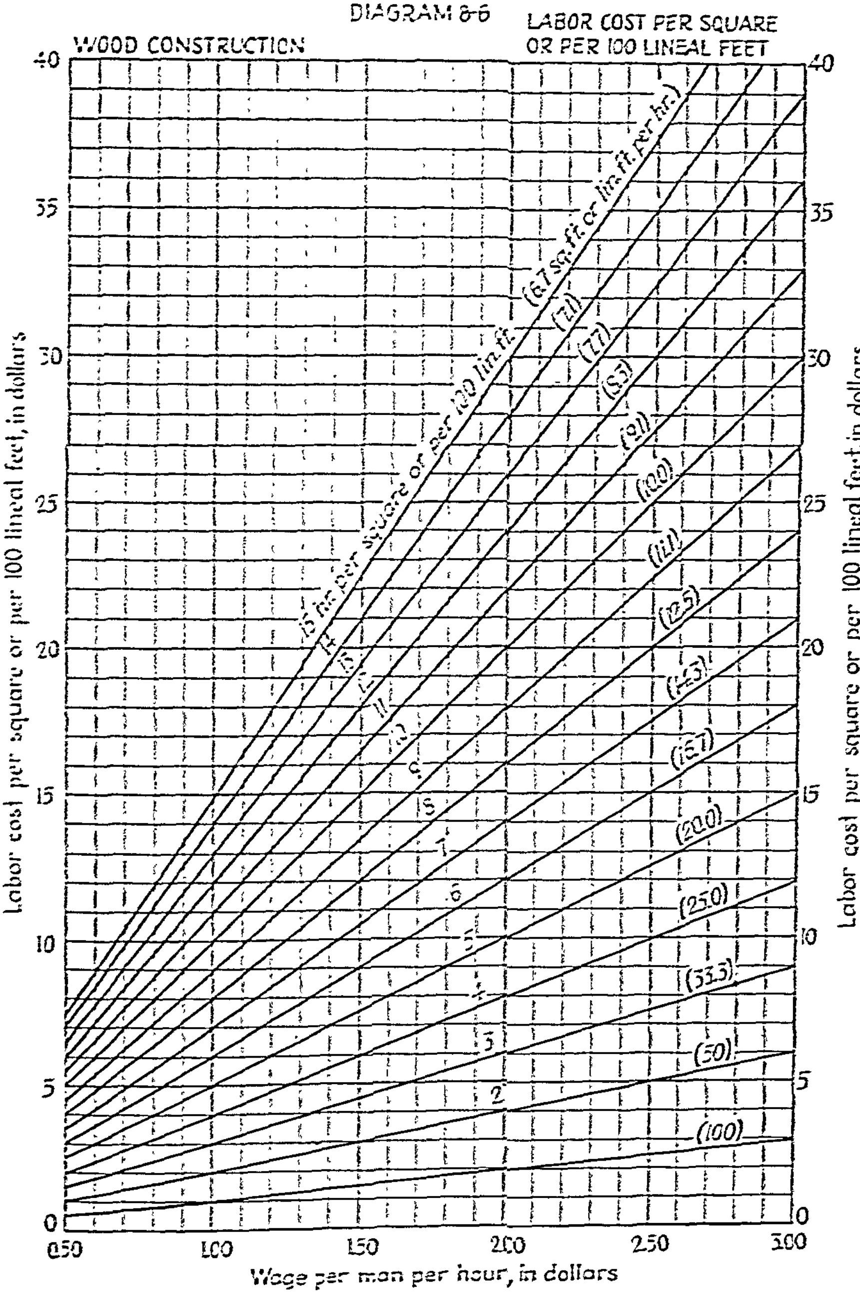

DIAGRAM 8-6.—Labor cost of wood construction per 100 lineal ft. or per square of 100 sq. ft.

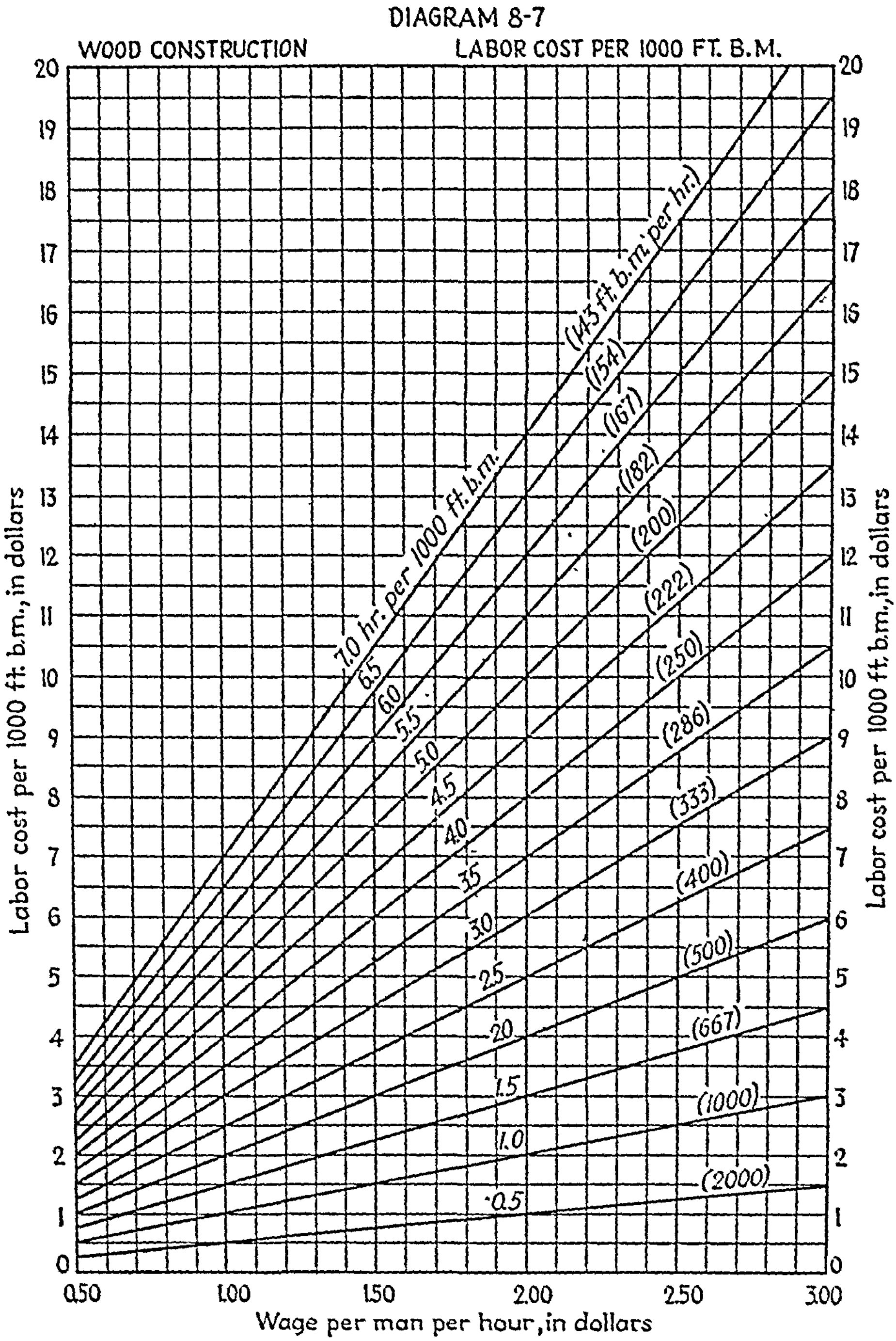

DIAGRAM 8-7.—Labor cost of wood construction per 1,000 ft. b.m.

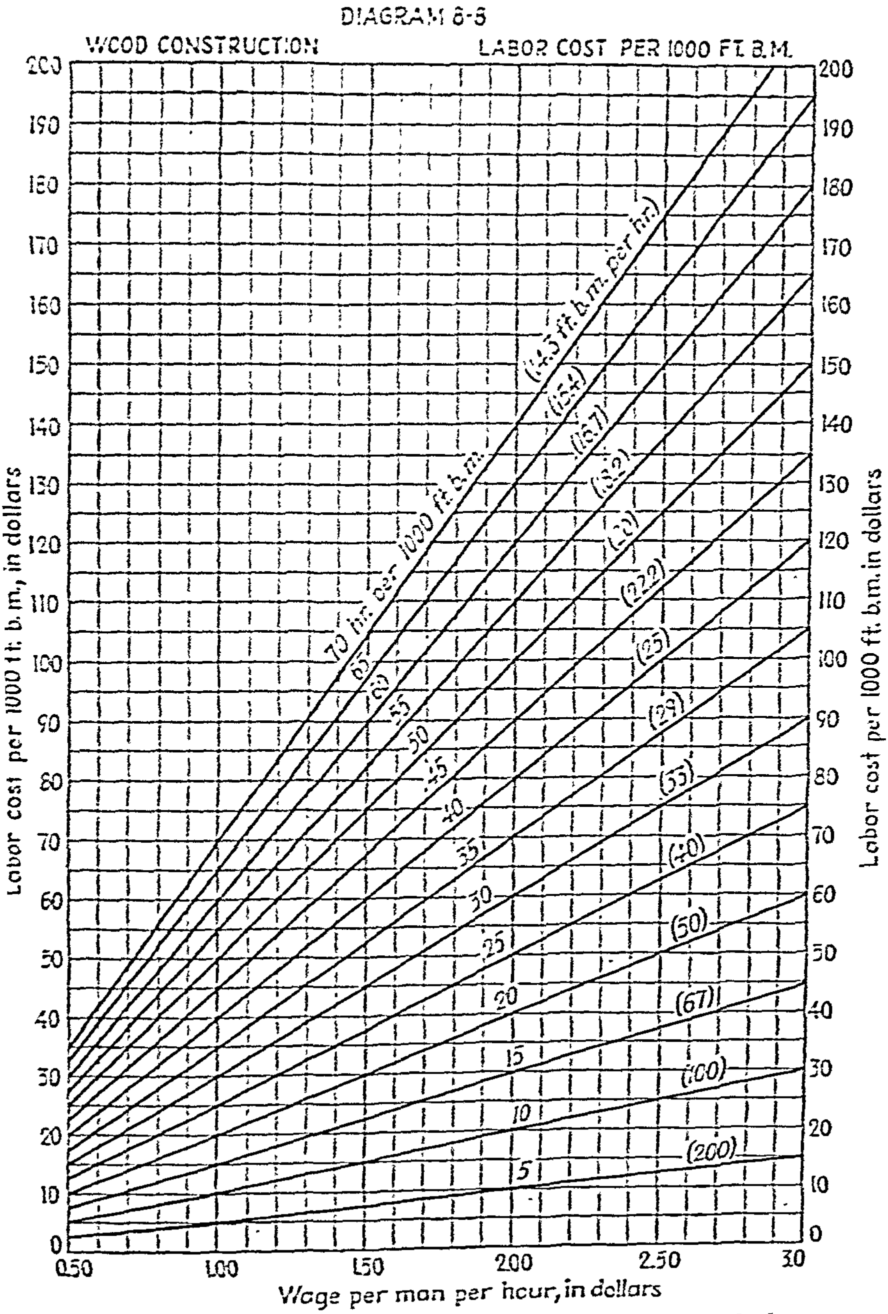

DIAGRAM 8-8.—Labor cost of wood construction per 1,000 ft. b.m.

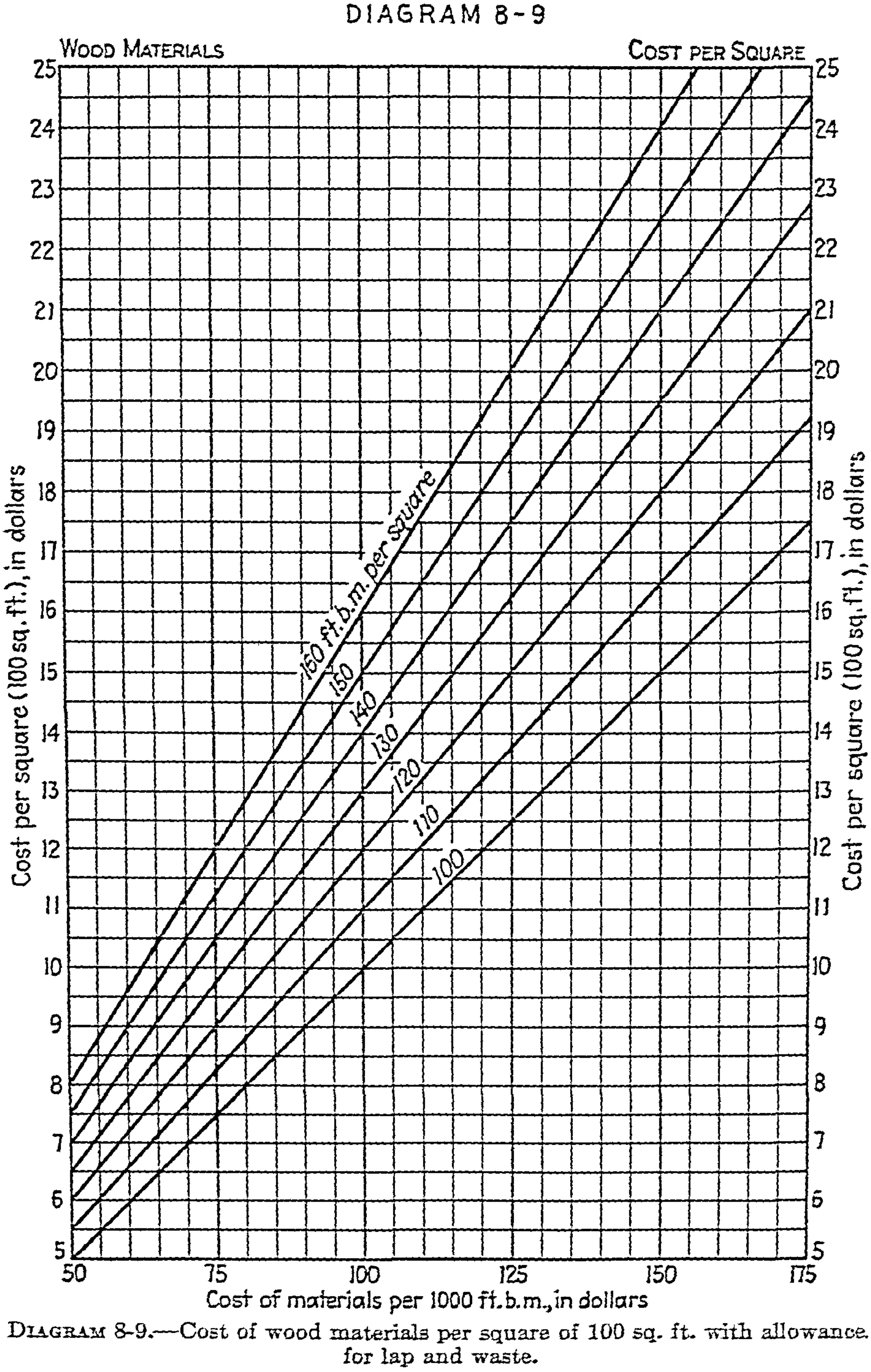

DIAGRAM 8-9.—Cost of wood materials per square of 100 sq. ft. with allowance for lap and waste.

DIAGRAM 9-1

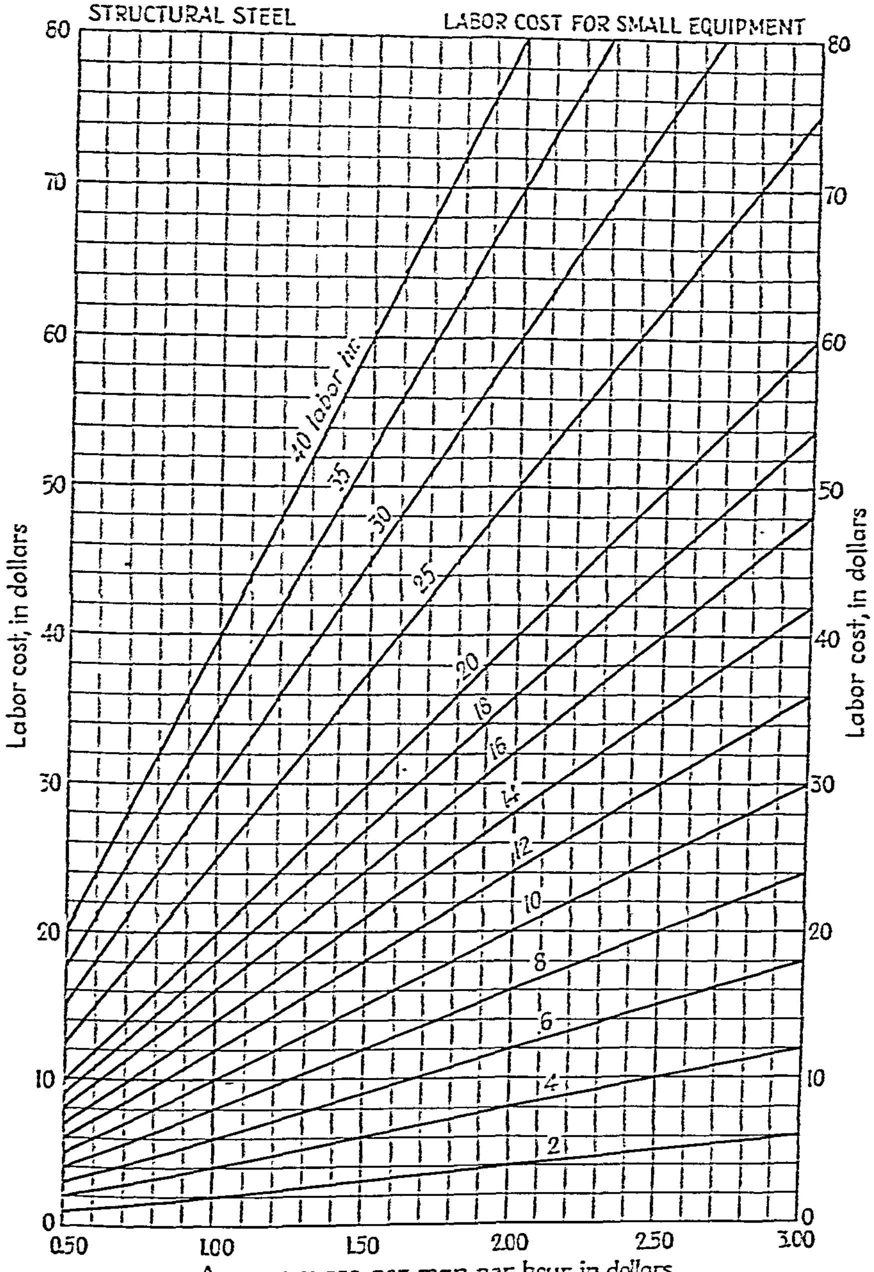

DIAGRAM 9-1.—Labor costs of erecting, moving, dismantling, loading, and unloading small- and medium-sized structural-steel equipment such as hoists, cranes, derricks, gin poles, air compressors, etc.

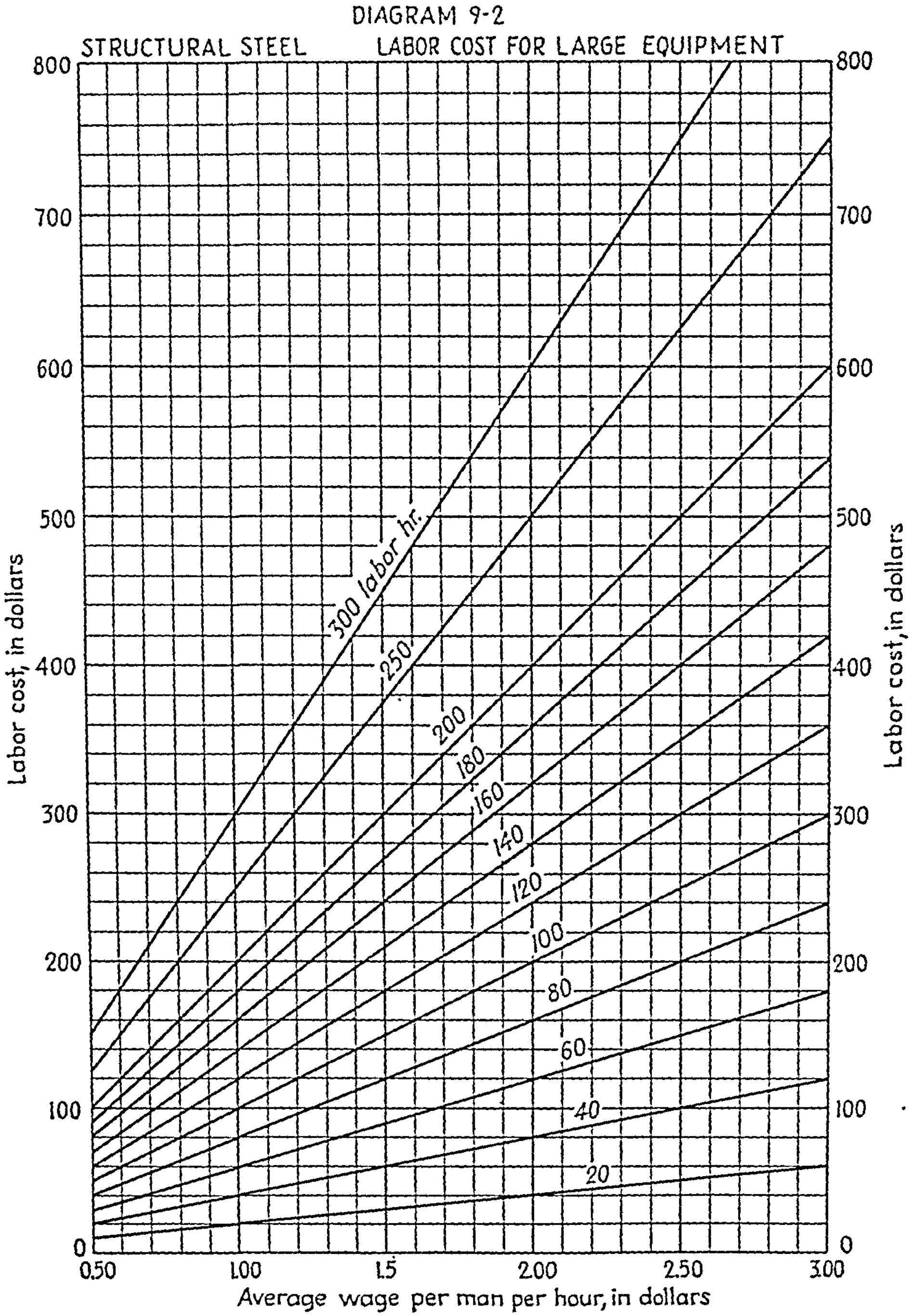

DIAGRAM 9-2.—Labor costs of erecting, moving, dismantling, loading, and unloading medium- and large-sized structural-steel equipment such as hoists. cranes. derricks, gin poles, air compressors, etc.

DIAGRAM 9-3

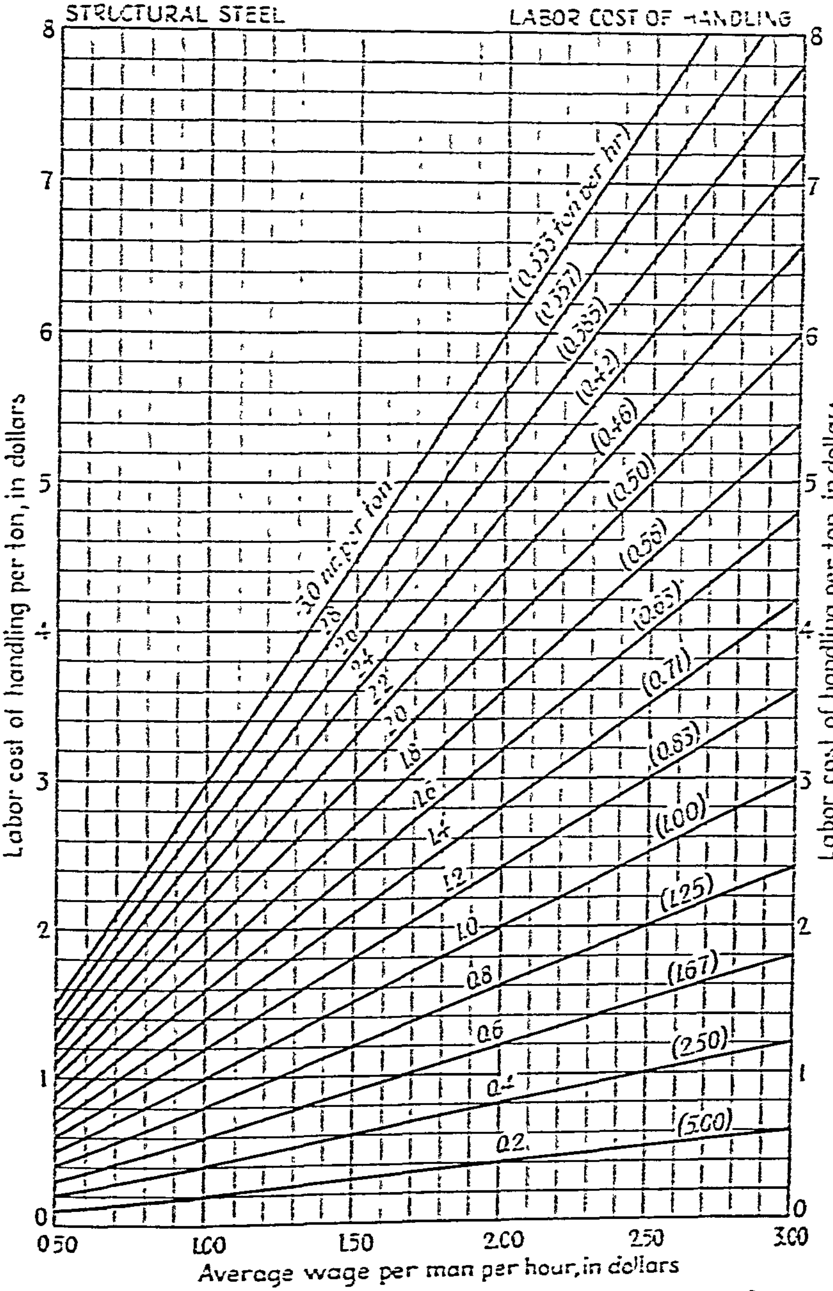

DIAGRAM 9-3.—Labor cost per ton of handling structural steel.

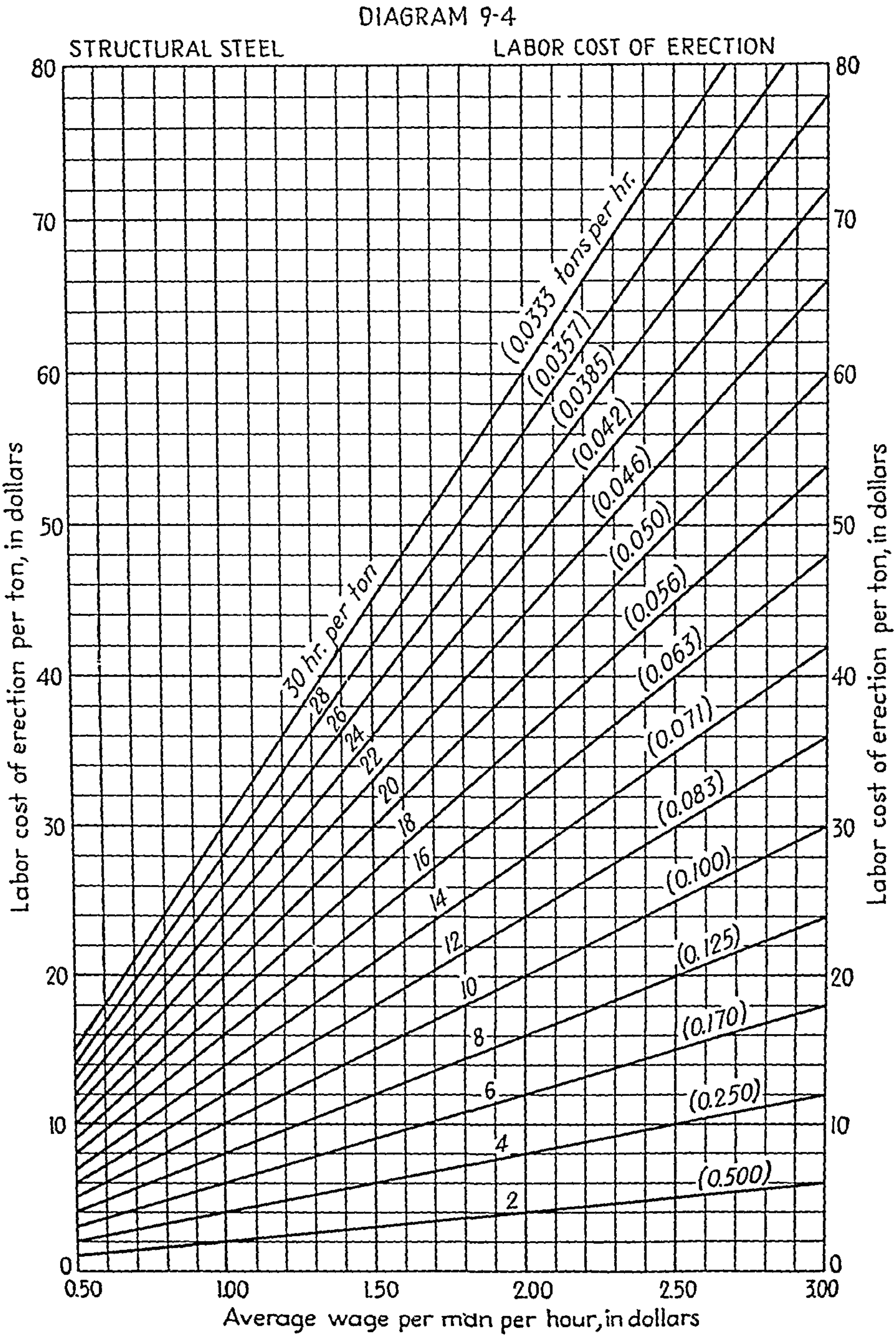

DIAGRAM 9-4.—Labor cost per ton of erecting structural steel.

DIAGRAM 9-5

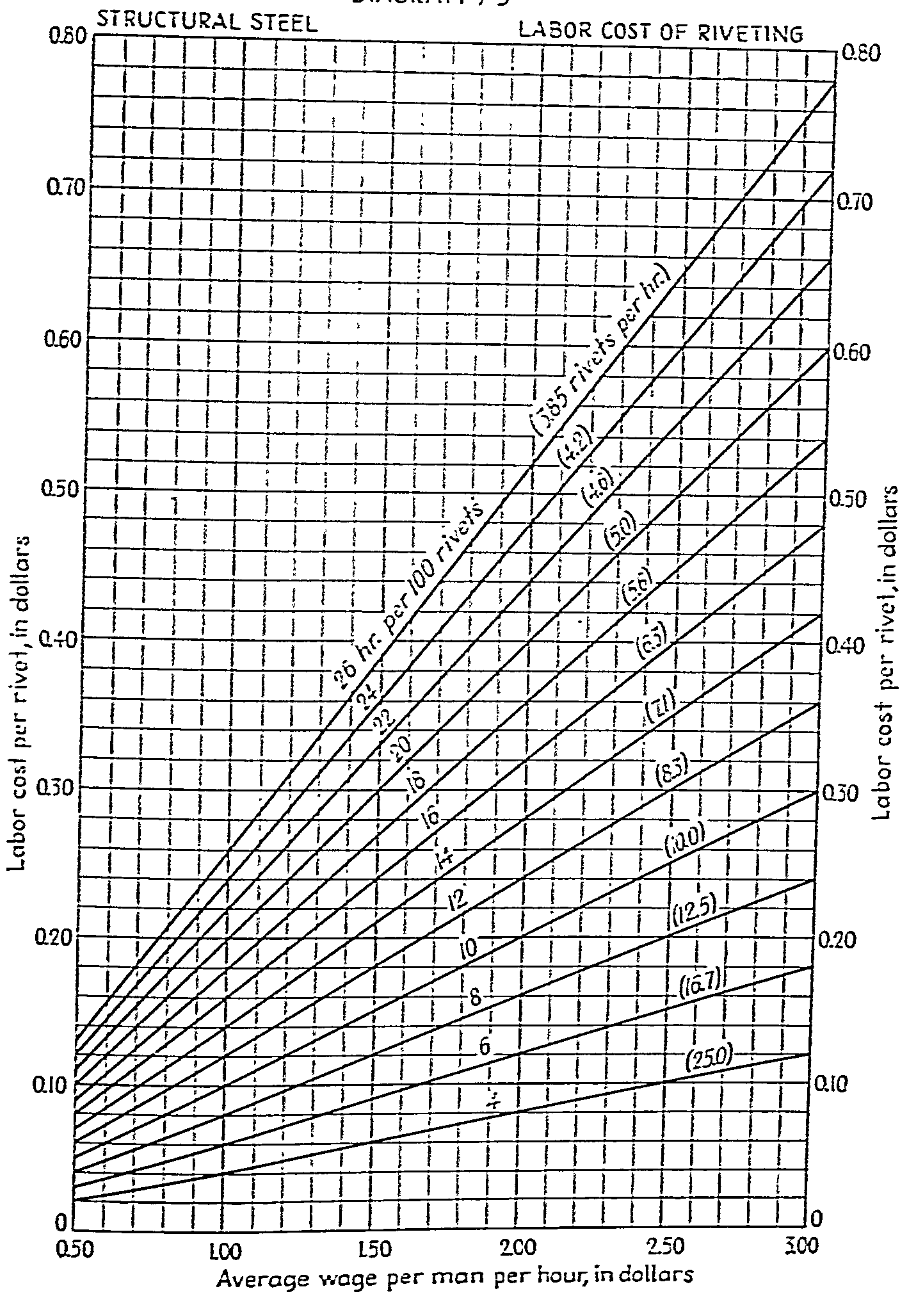

DIAGRAM 9-5.—Labor cost of riveting structural steel.

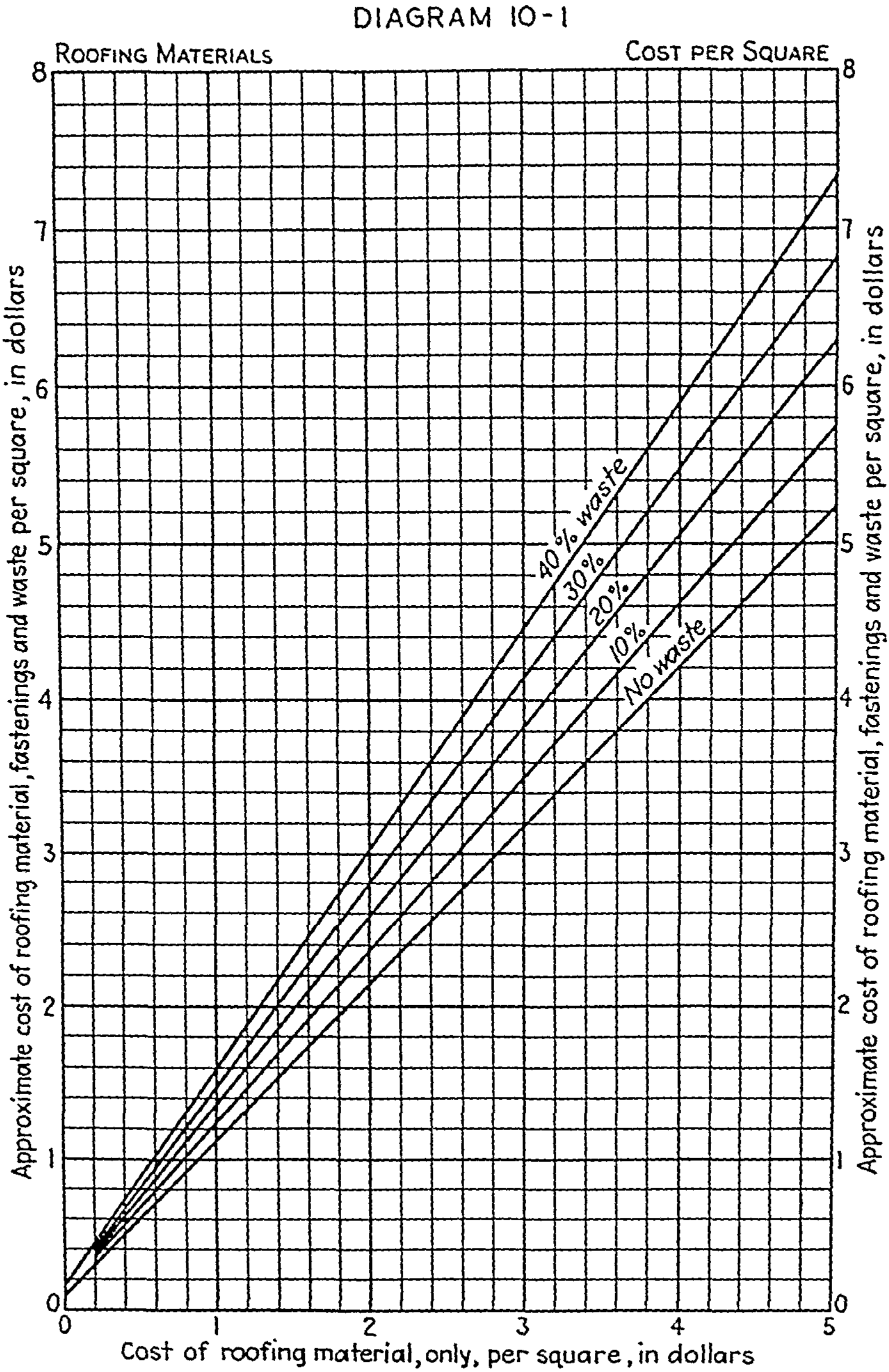

DIAGRAM 10-1.—Approximate cost of roofing materials per square with allowances for fastenings and waste.

DIAGRAM 10-2

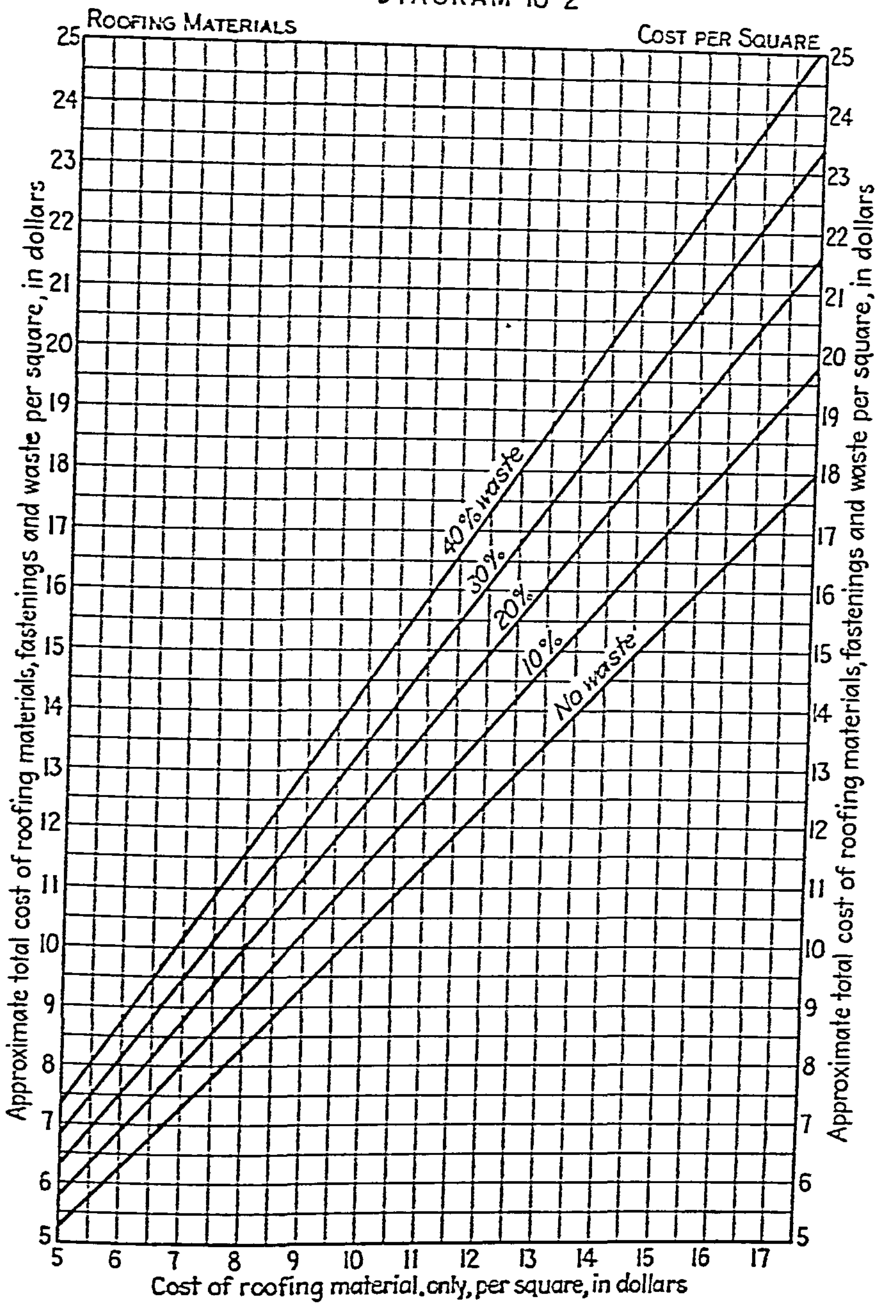

Diagram 10-2.—Approximate cost of roofing materials per square with allowances for fastenings and waste.

DIAGRAM 10-3

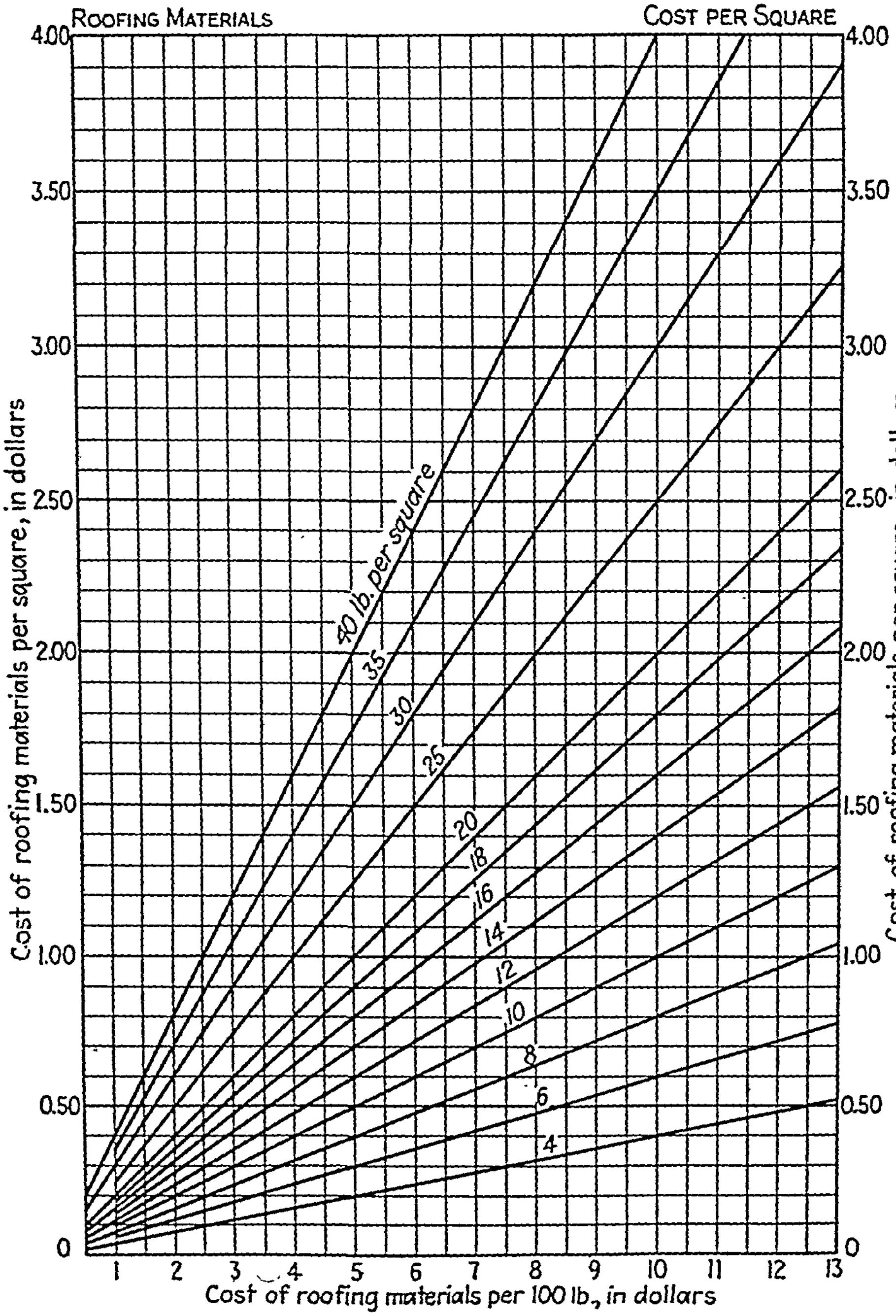

DIAGRAM 10-3.—Cost of roofing materials per square of roof area.

DIAGRAM 10-4

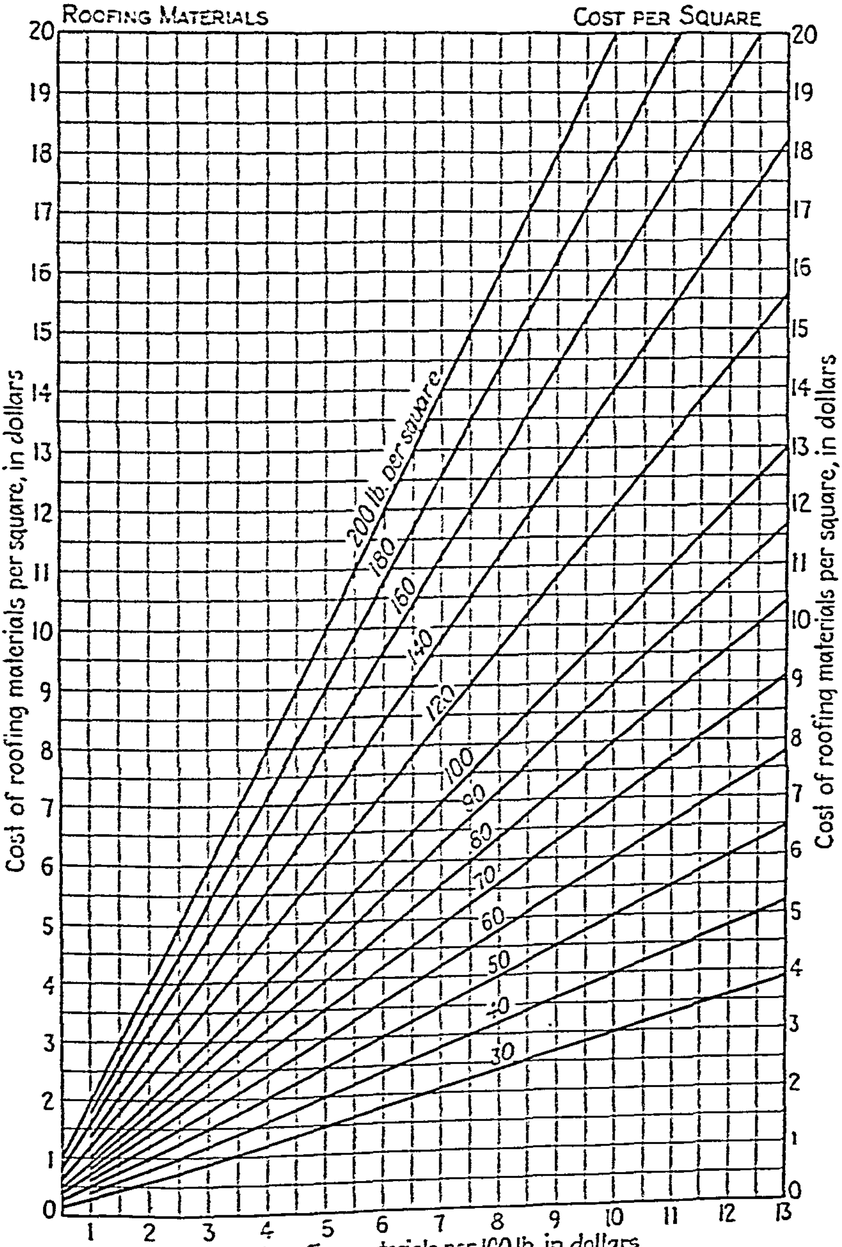

DIAGRAM 10-4.—Cost of roofing materials per square of roof area.

DIAGRAM 10-5

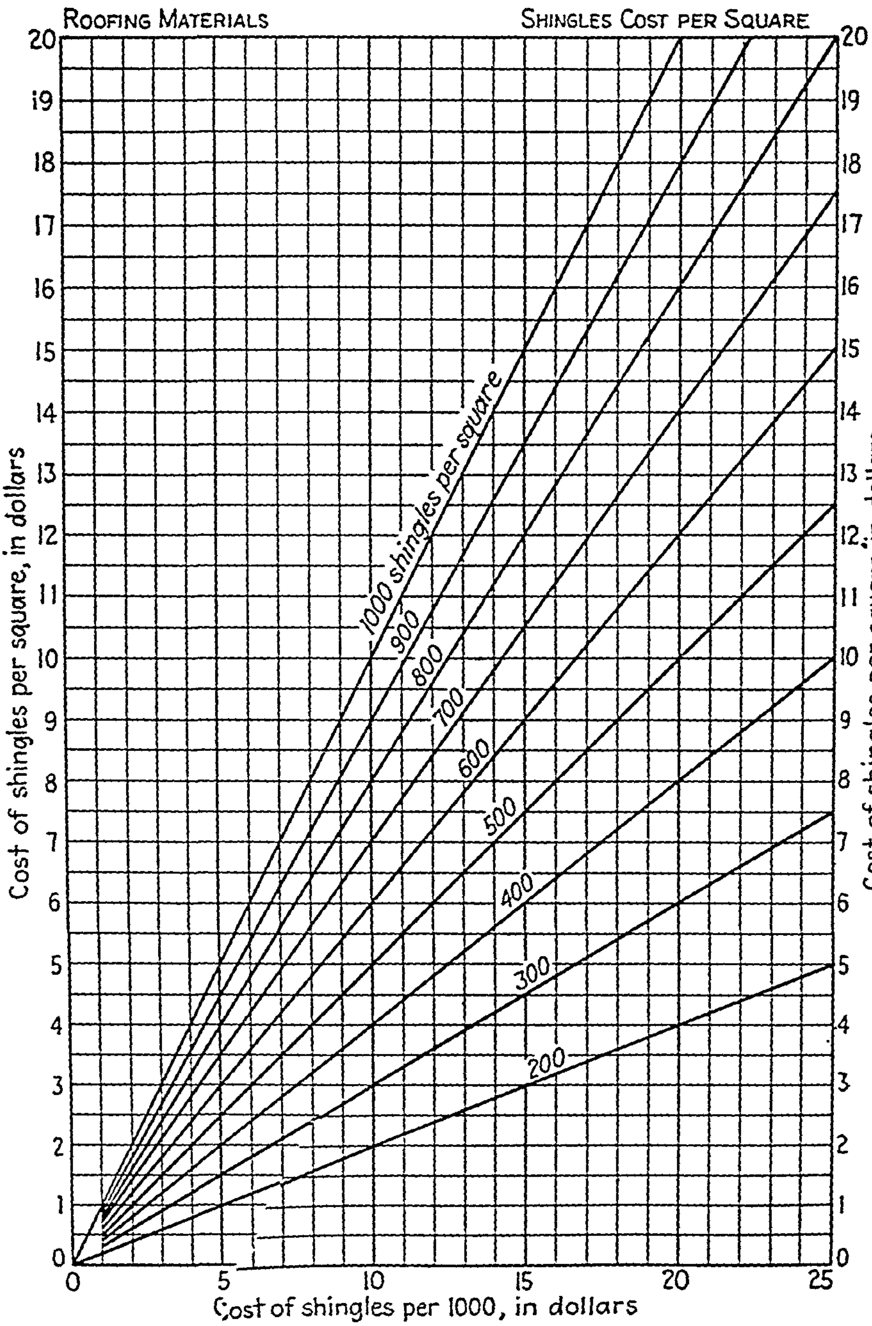

DIAGRAM 10-5.—Cost of shingles per square of roof area.

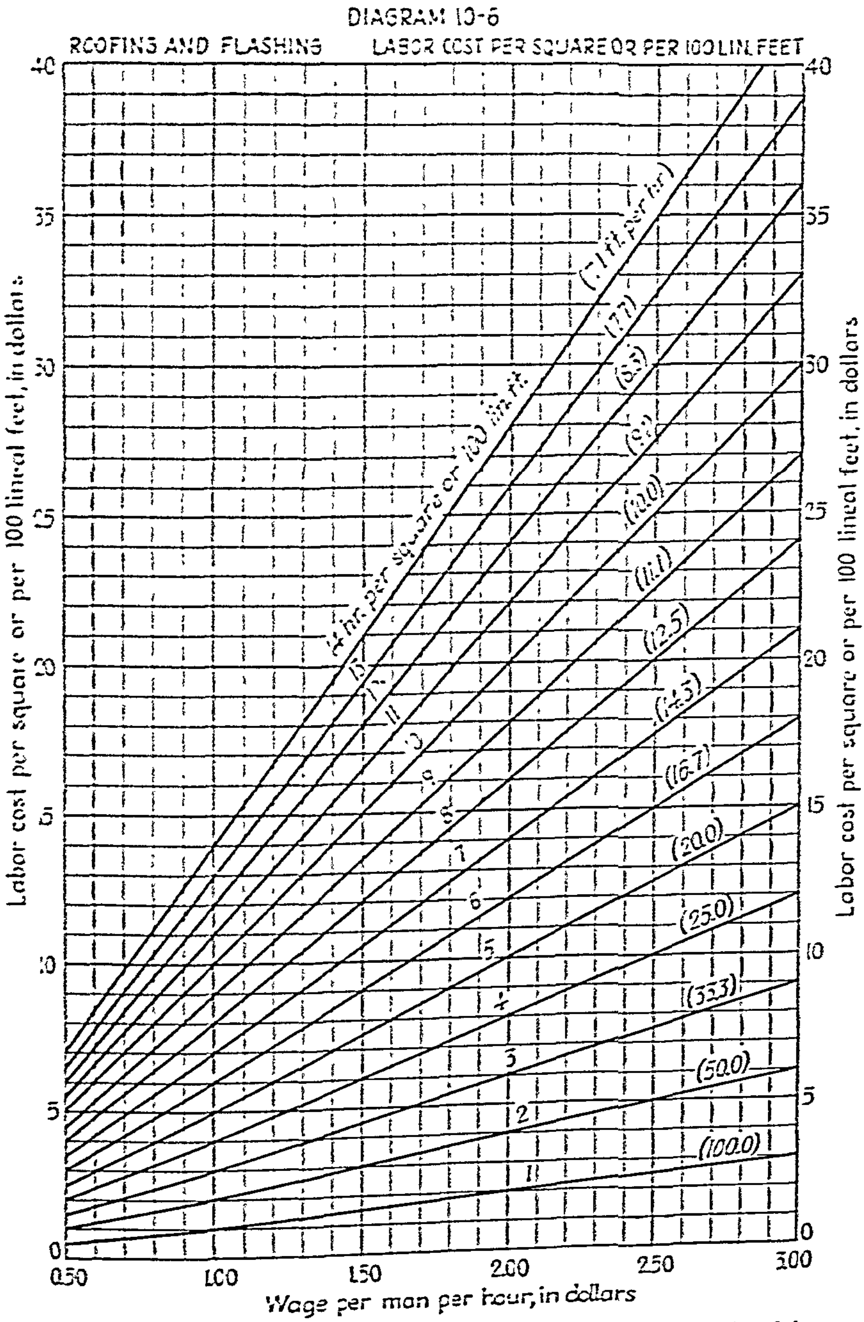

DIAGRAM 10-6.—Labor cost of roofing per square or per 100 lineal ft.

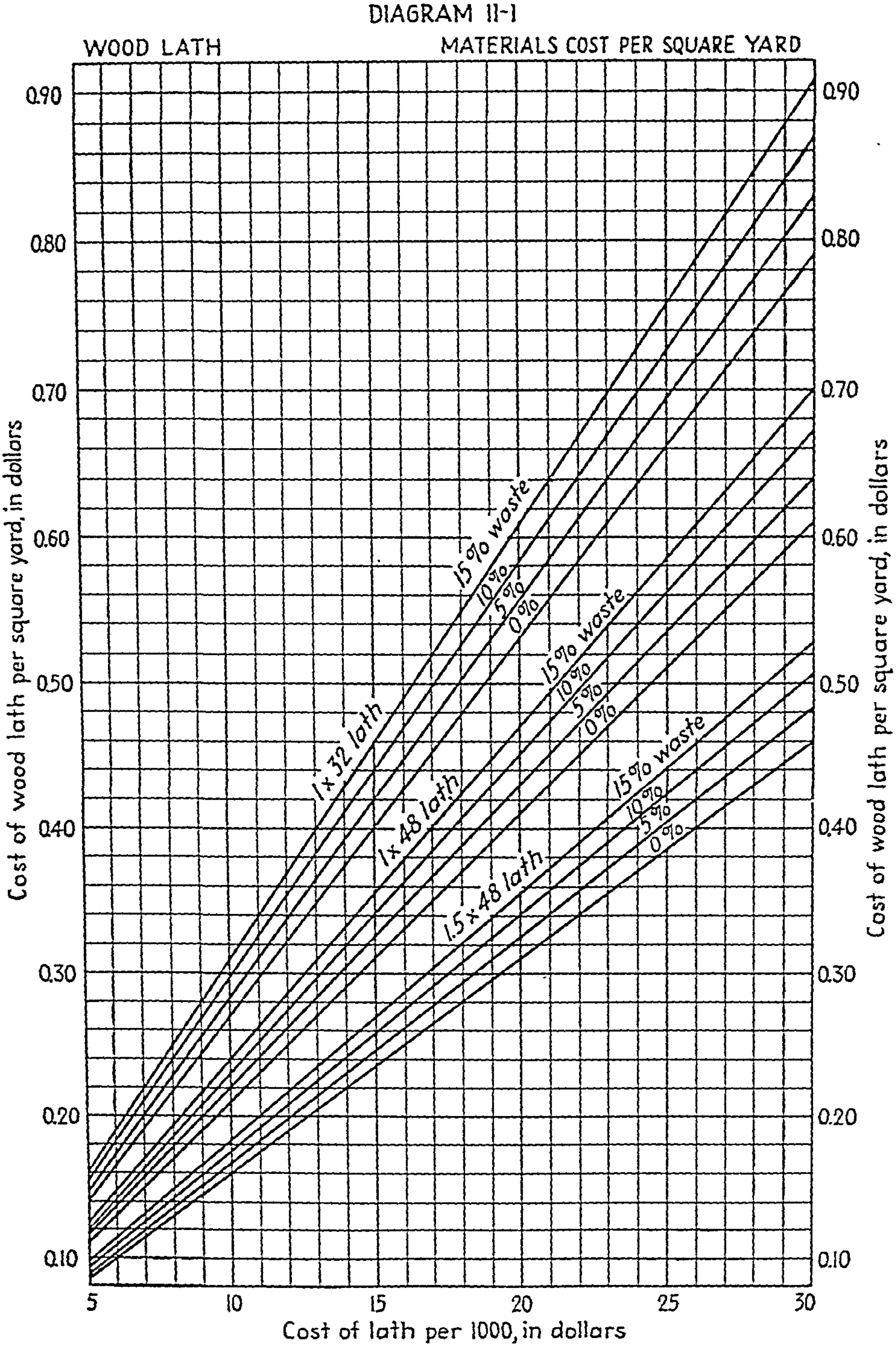

DIAGRAM 11-1.—Cost of wood lath per square yard with an allowance of $0.01 per square yard for nails and varying allowances for waste.

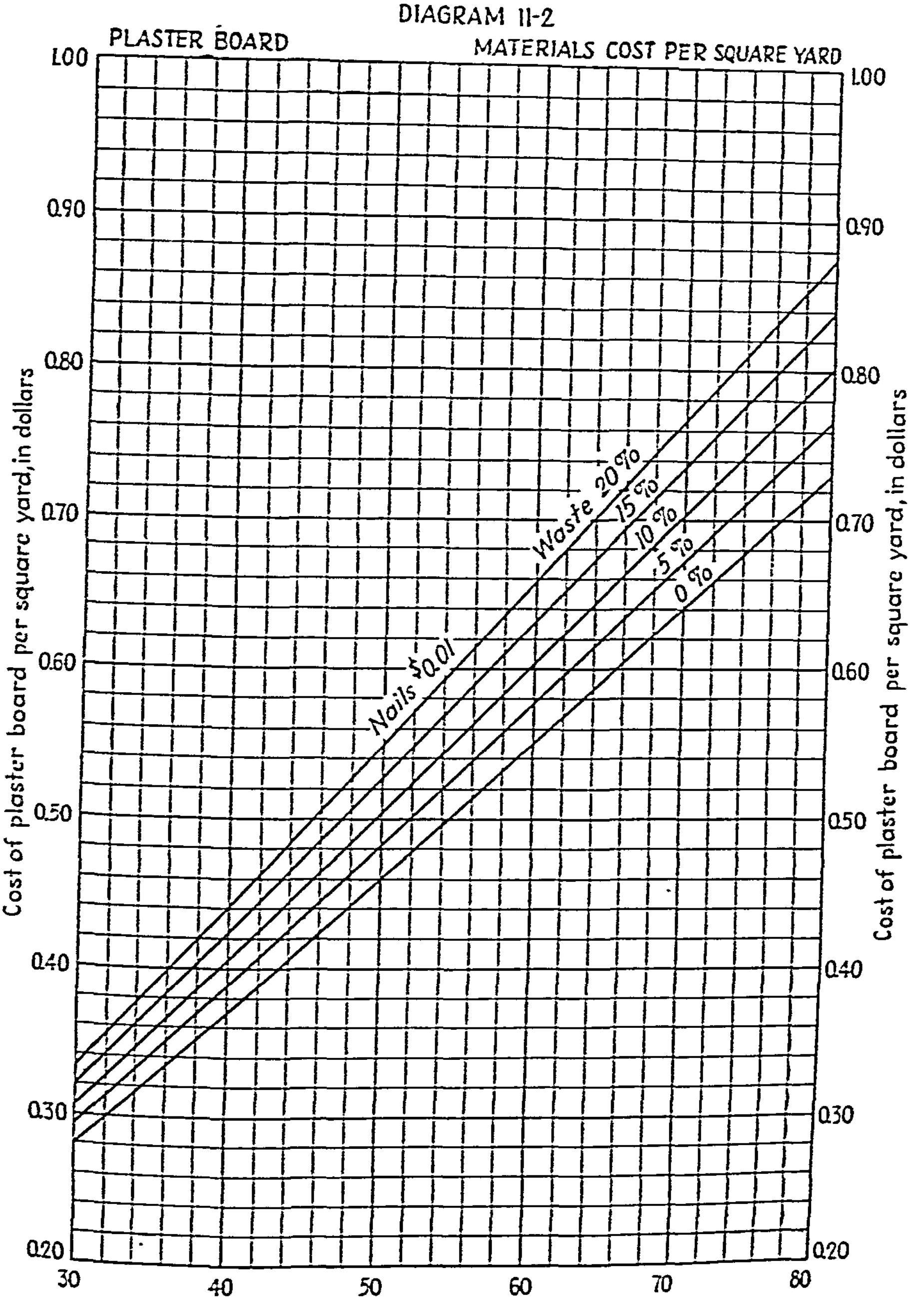

DIAGRAM 11-2.—Cost of plaster board per square yard with an allowance of $0.01 per square yard for nails and varying allowances for waste.

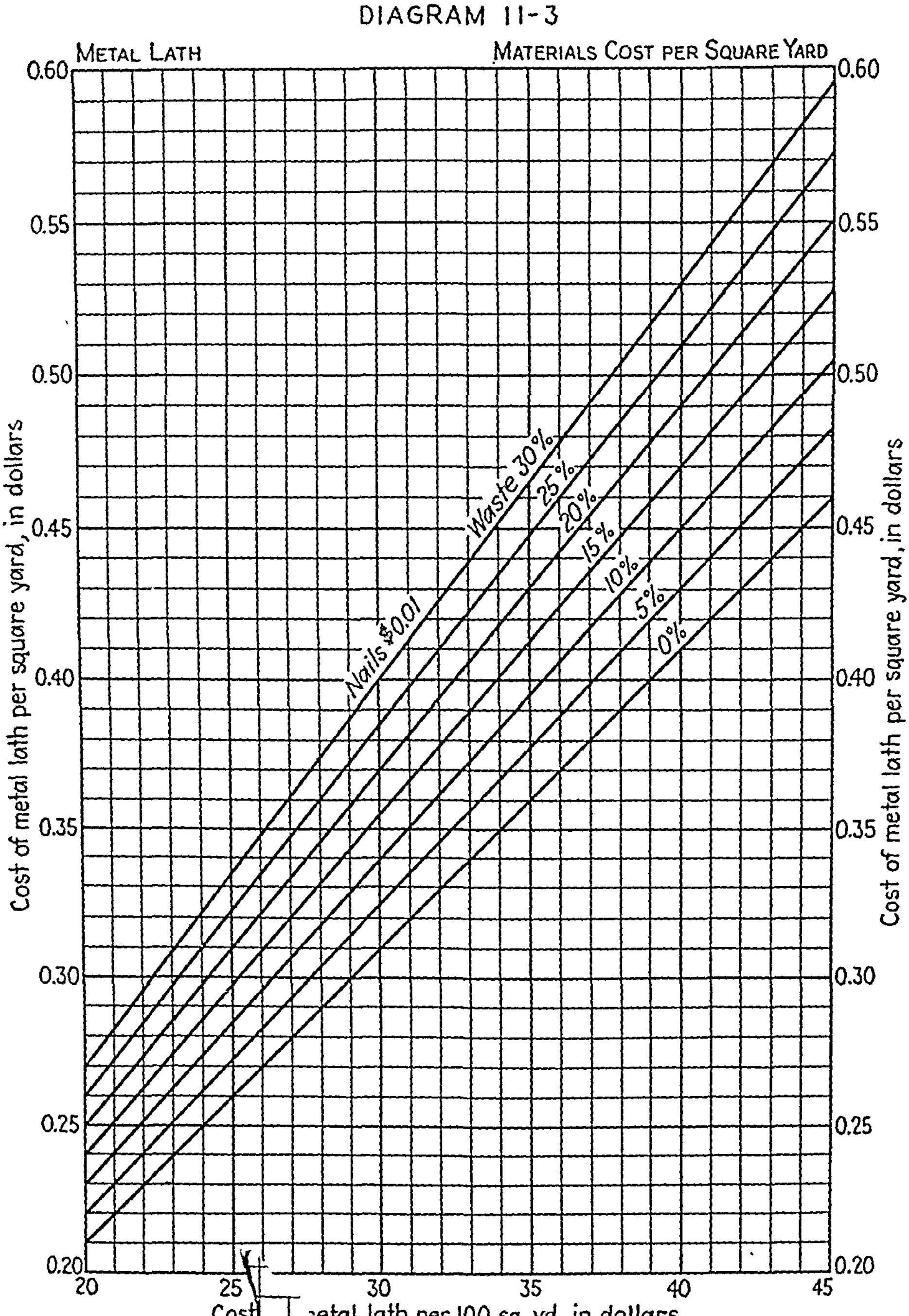

DIAGRAM 11-3.—Cost ... al lath per square yard with an allowance of $0.01 per square y... nails and varying allowances for waste.

Cost c
wood lat
r nails a

DIAGRAM 11-4

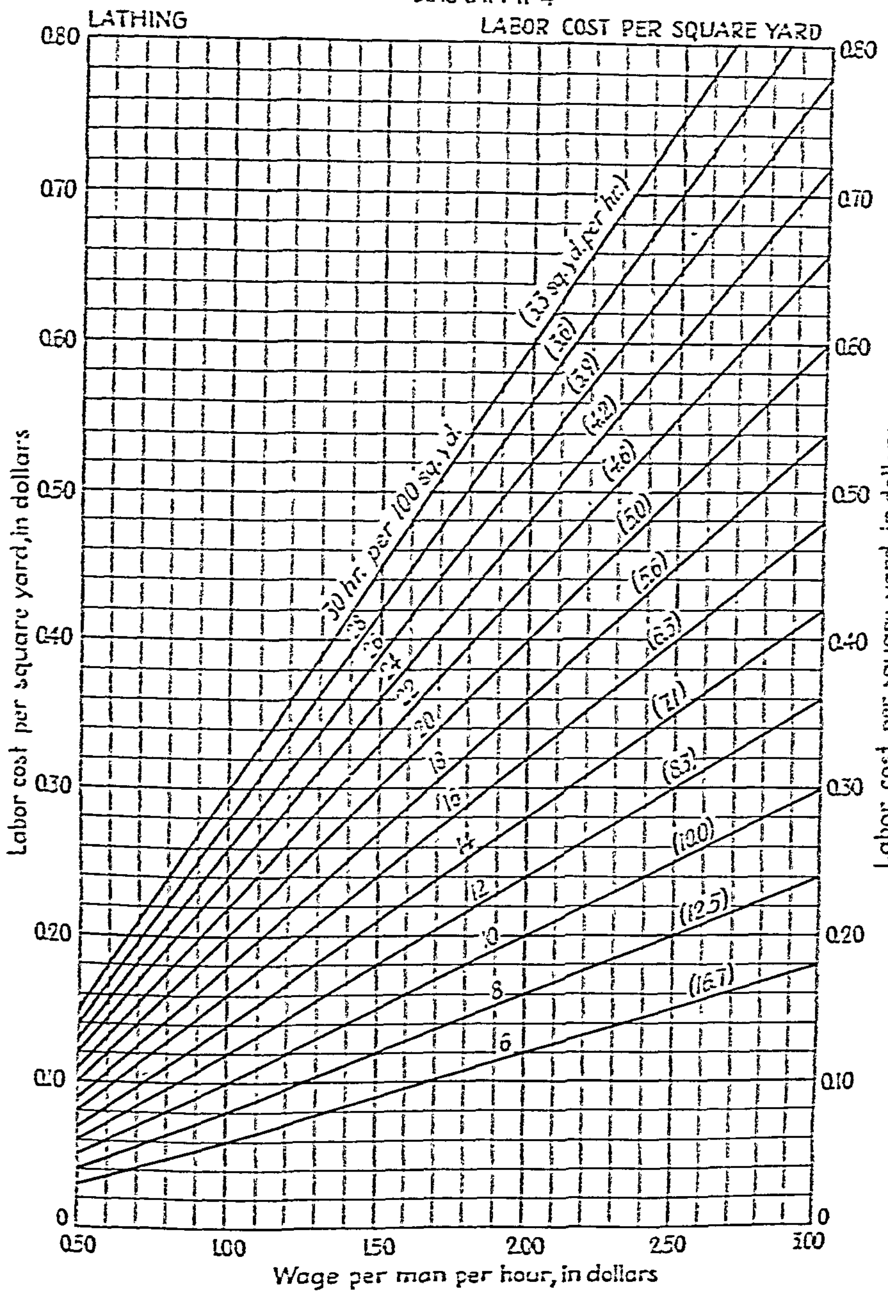

DIAGRAM 11-4.—Labor cost per square yard of applying lath and plaster board.

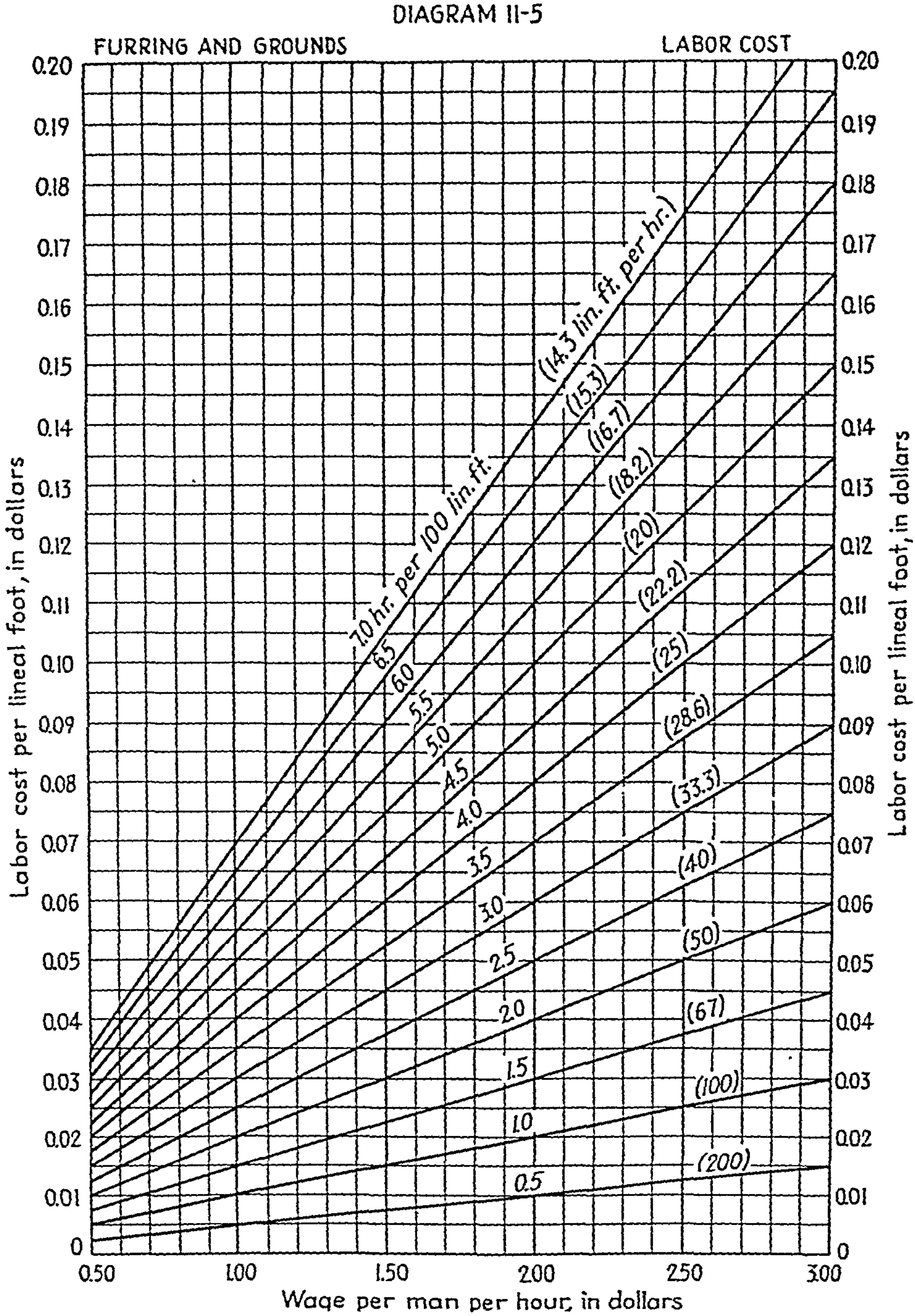

DIAGRAM 11-5.—Labor cost of applying furring, grounds, corners, corner bead, etc.

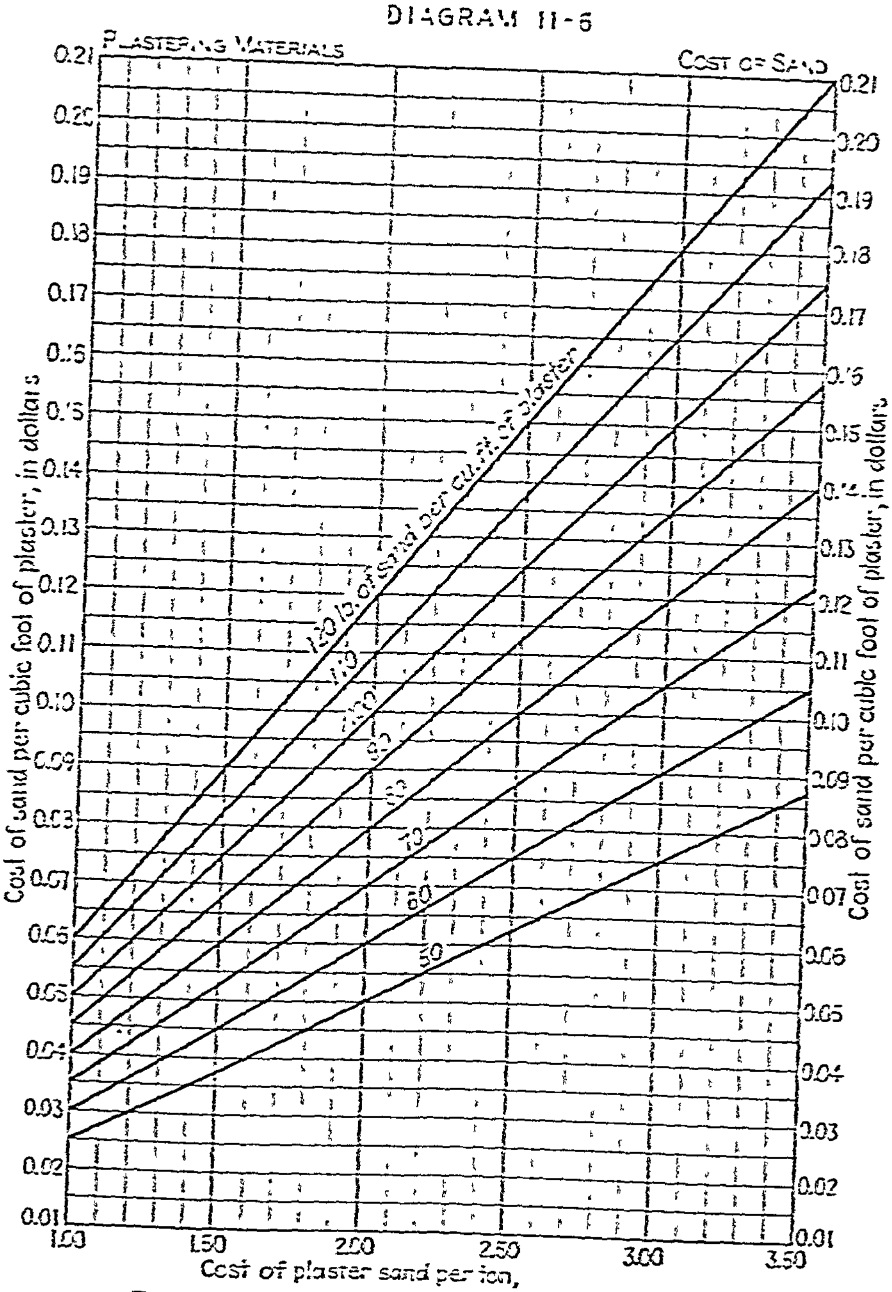

DIAGRAM 11-6.—Cost of sand per cubic foot of plaster.

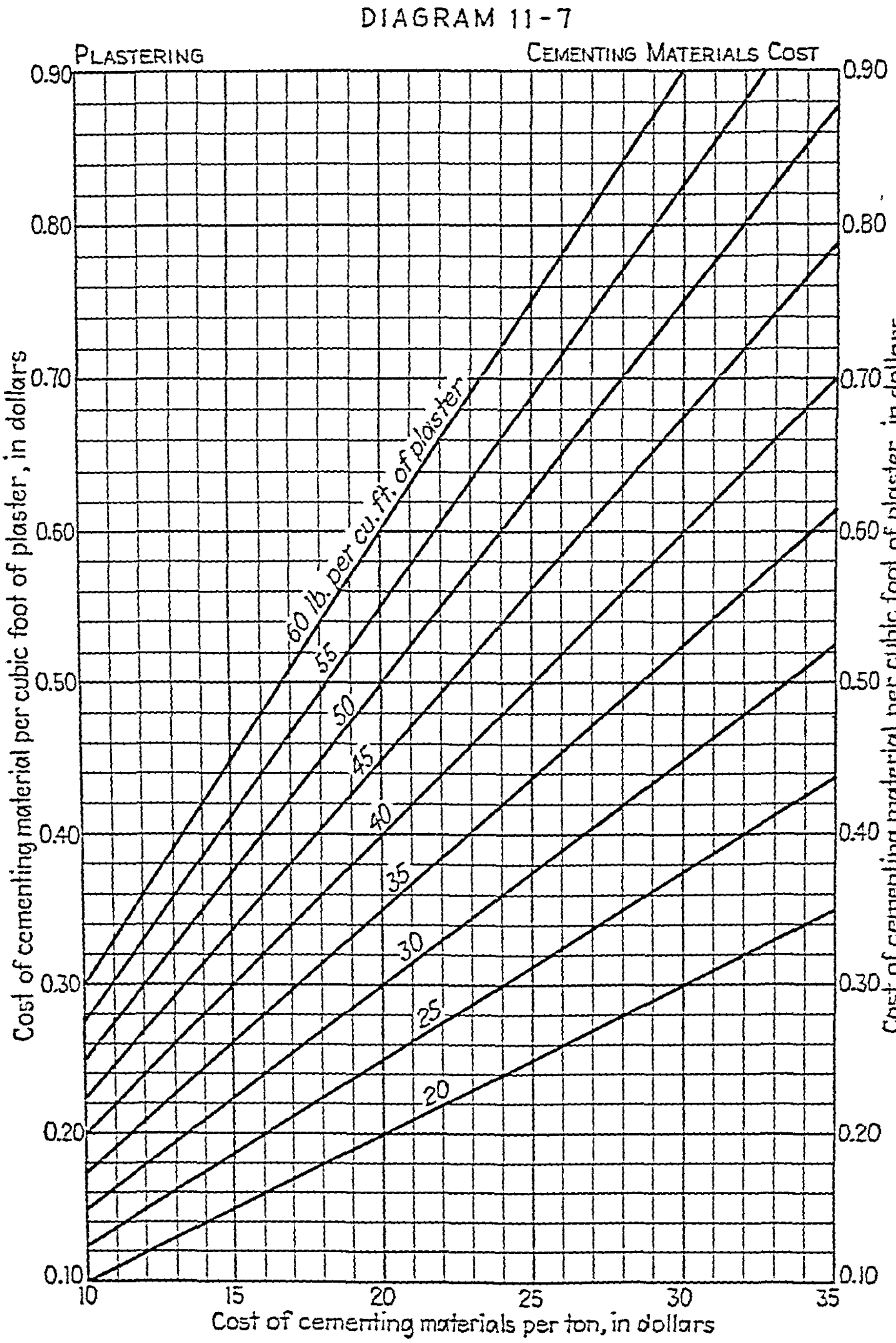

DIAGRAM 11-7.—Cost of cementing materials (lime, gypsum, plaster cemen etc.) per cubic foot of plaster.

DIAGRAM 11-8

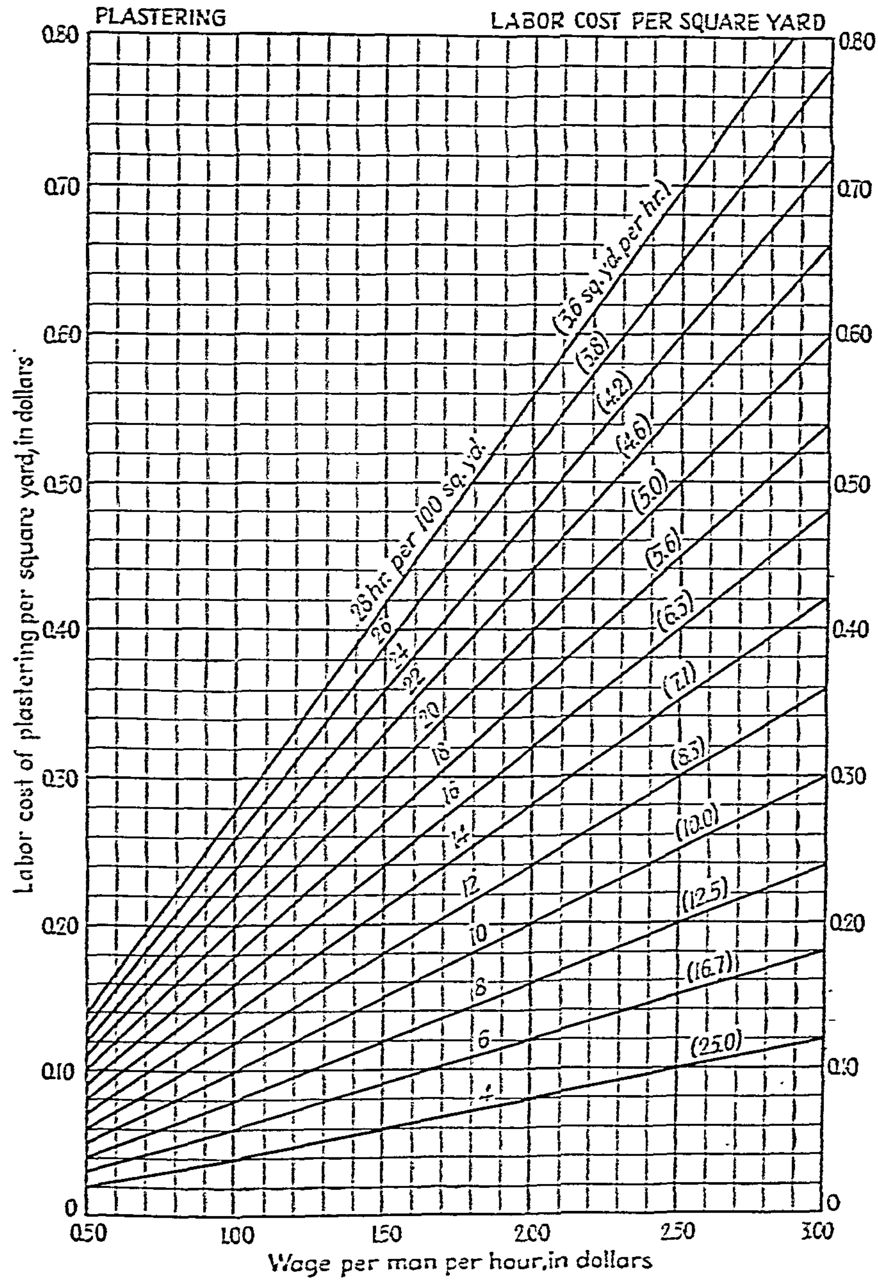

DIAGRAM 11-8.—Labor cost per square yard of plastering.

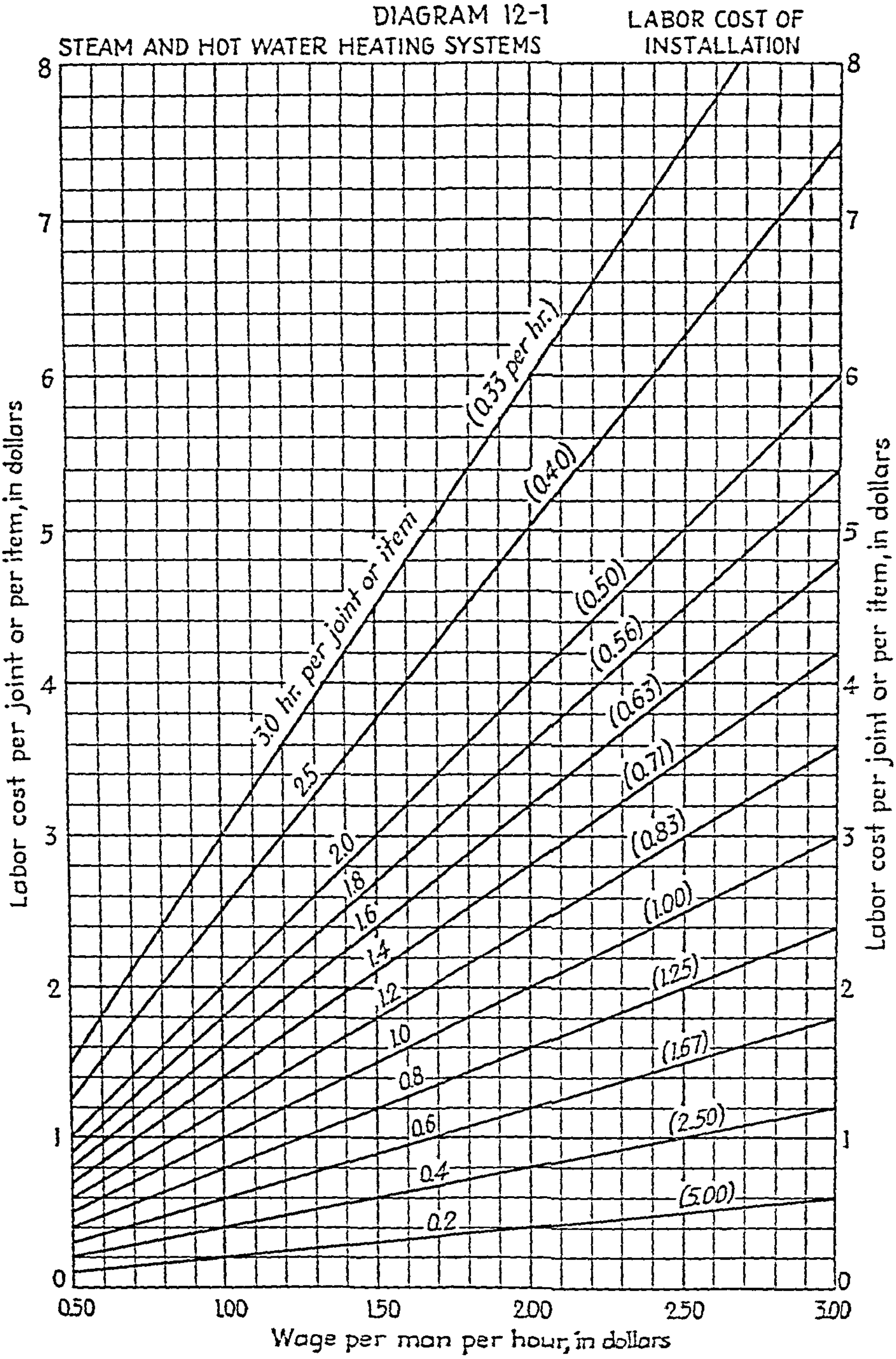

DIAGRAM 12-1.—Labor costs of installing pipe and other items in steam and hot-water heating systems.

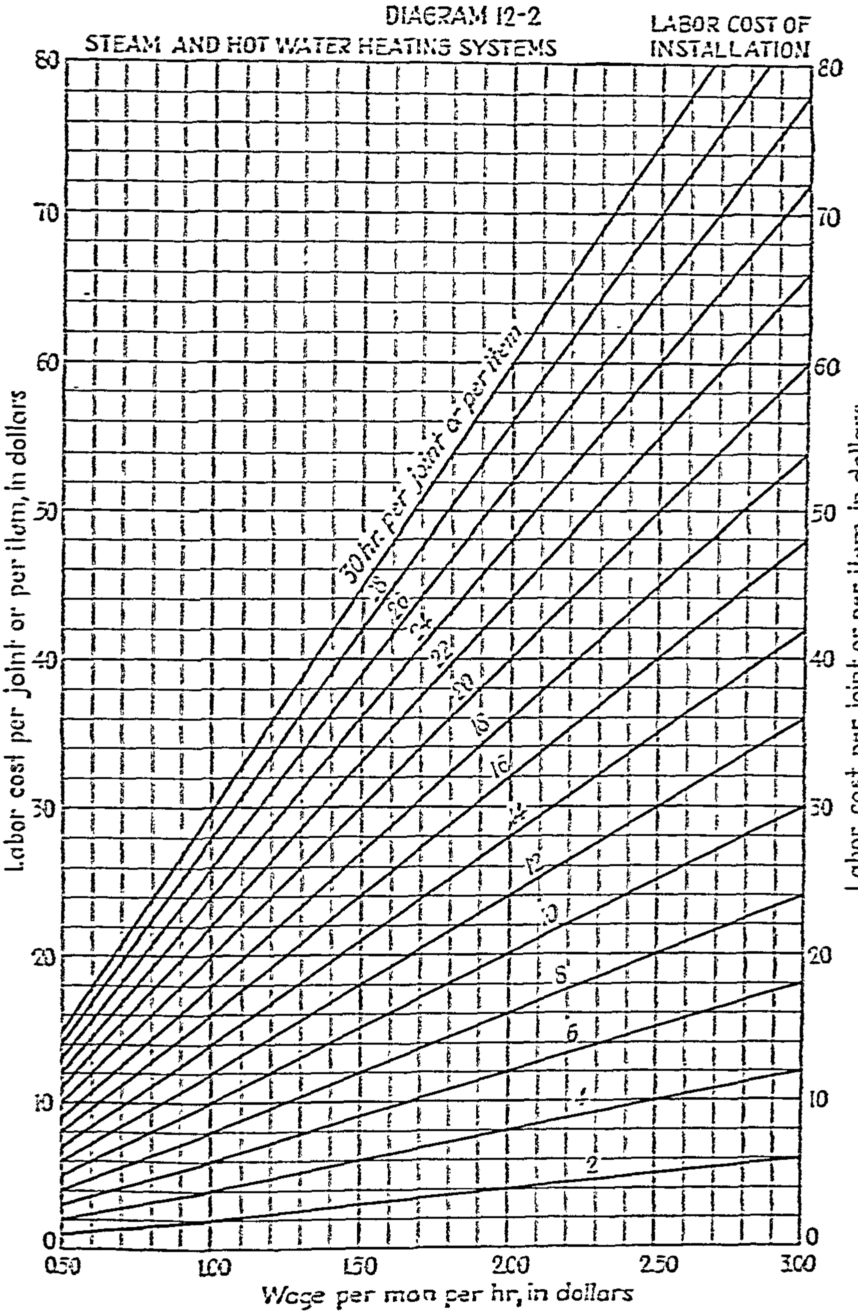

DIAGRAM 12-2.—Labor costs of installing pipe and other items in steam- and hot-water heating systems.

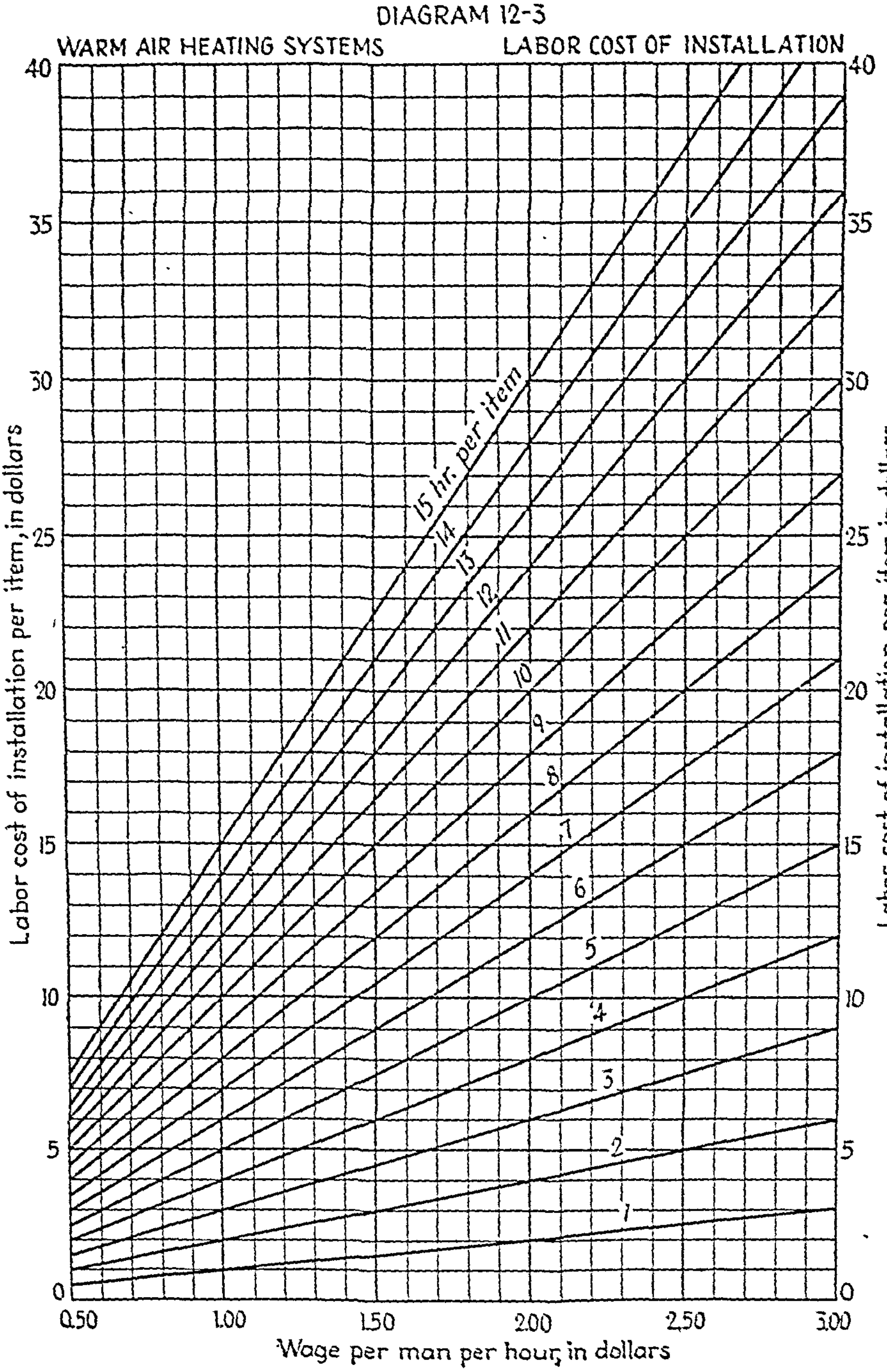

DIAGRAM 12-3.—Labor costs of installing parts of warm-air heating systems.

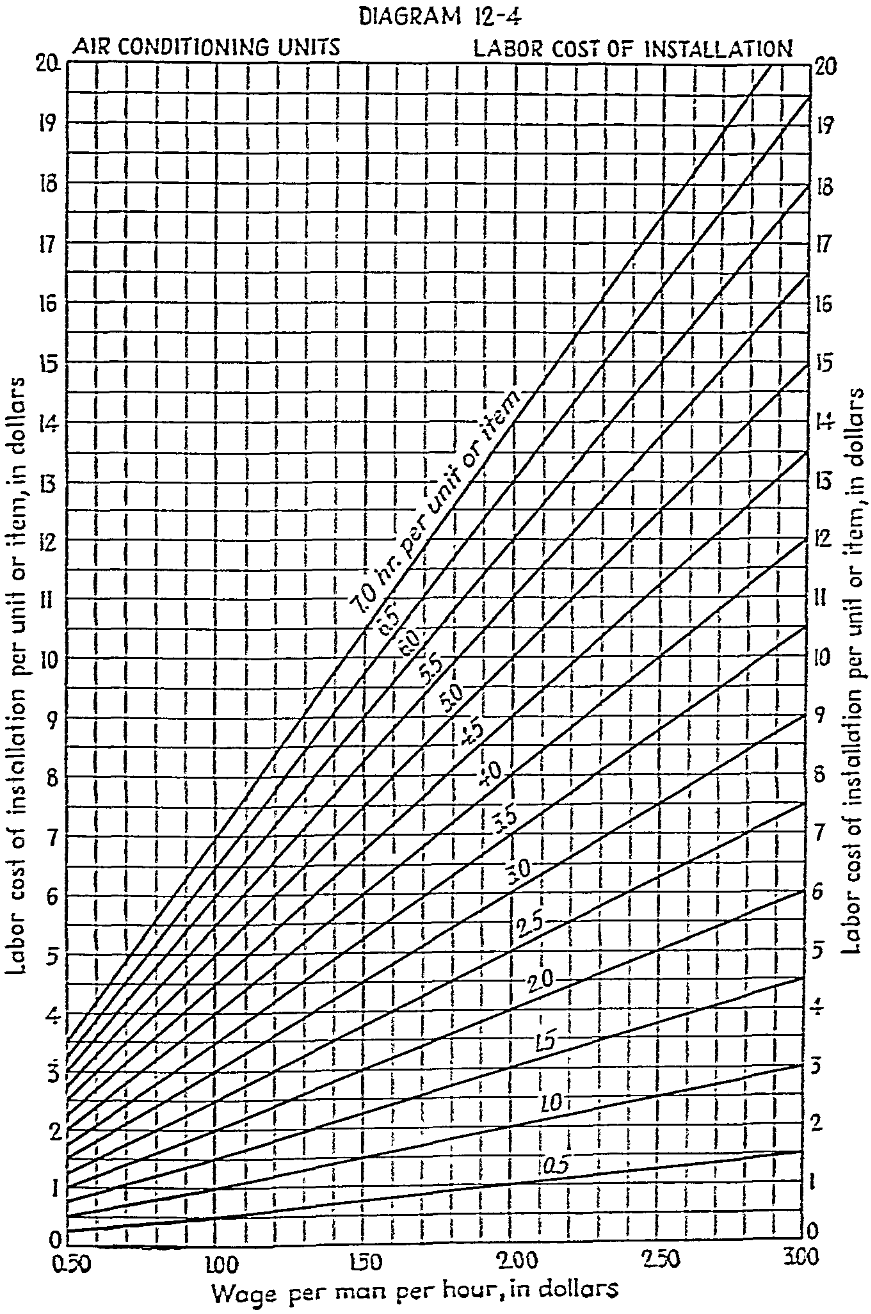

DIAGRAM 12-4.—Labor cost per item of installing air-conditioning units.

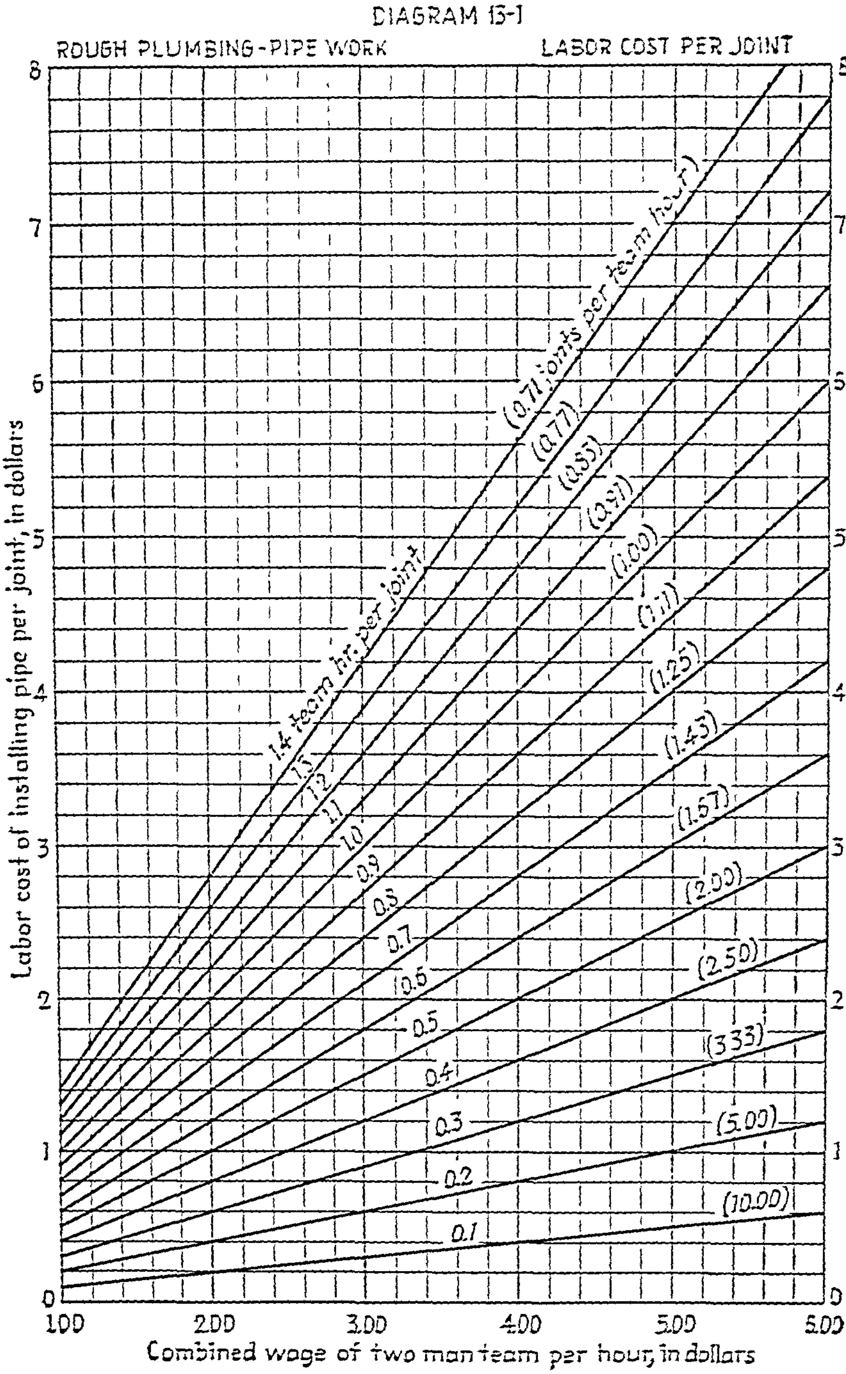

Diagram 13-1.—Labor cost of installing pipe per joint.

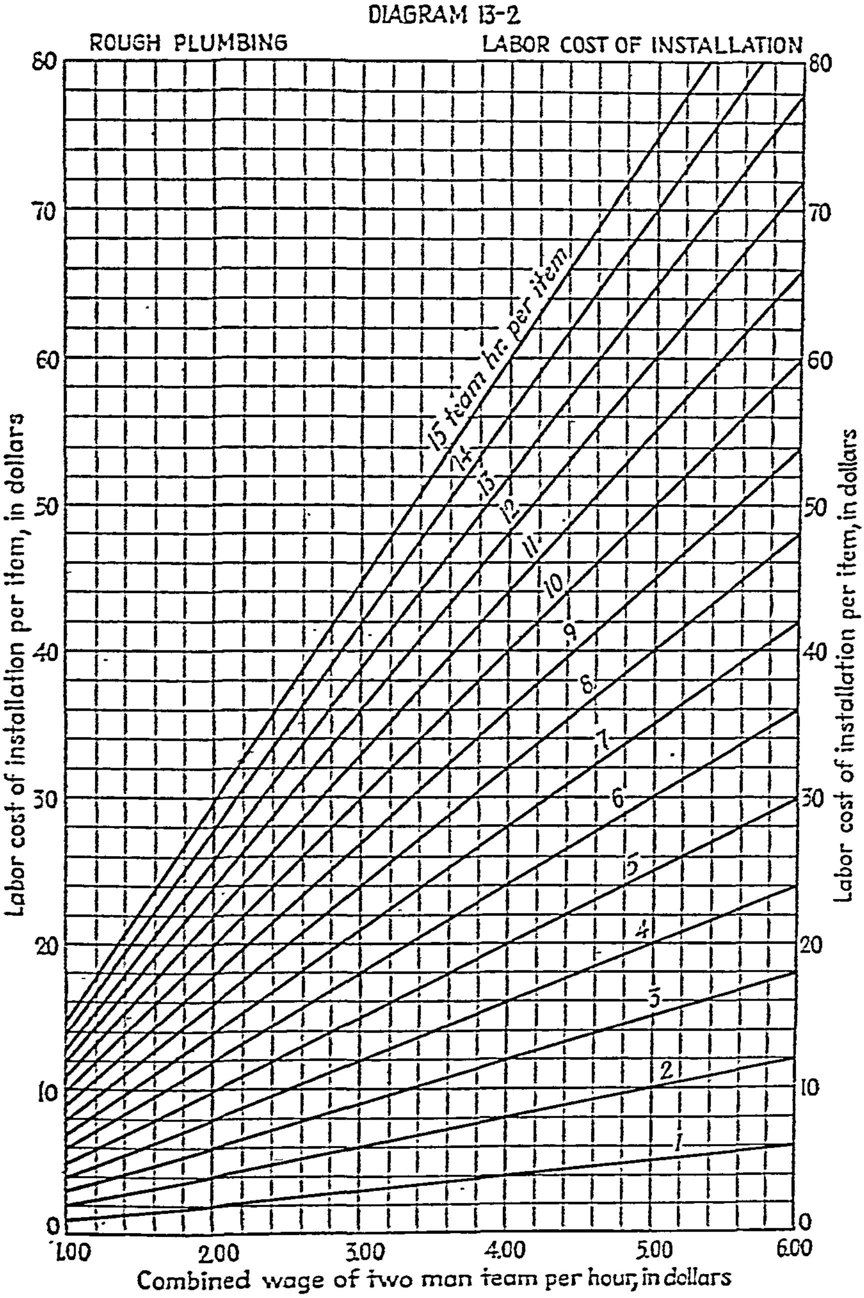

DIAGRAM 13-2.—Labor cost of installing rough plumbing work, per item.

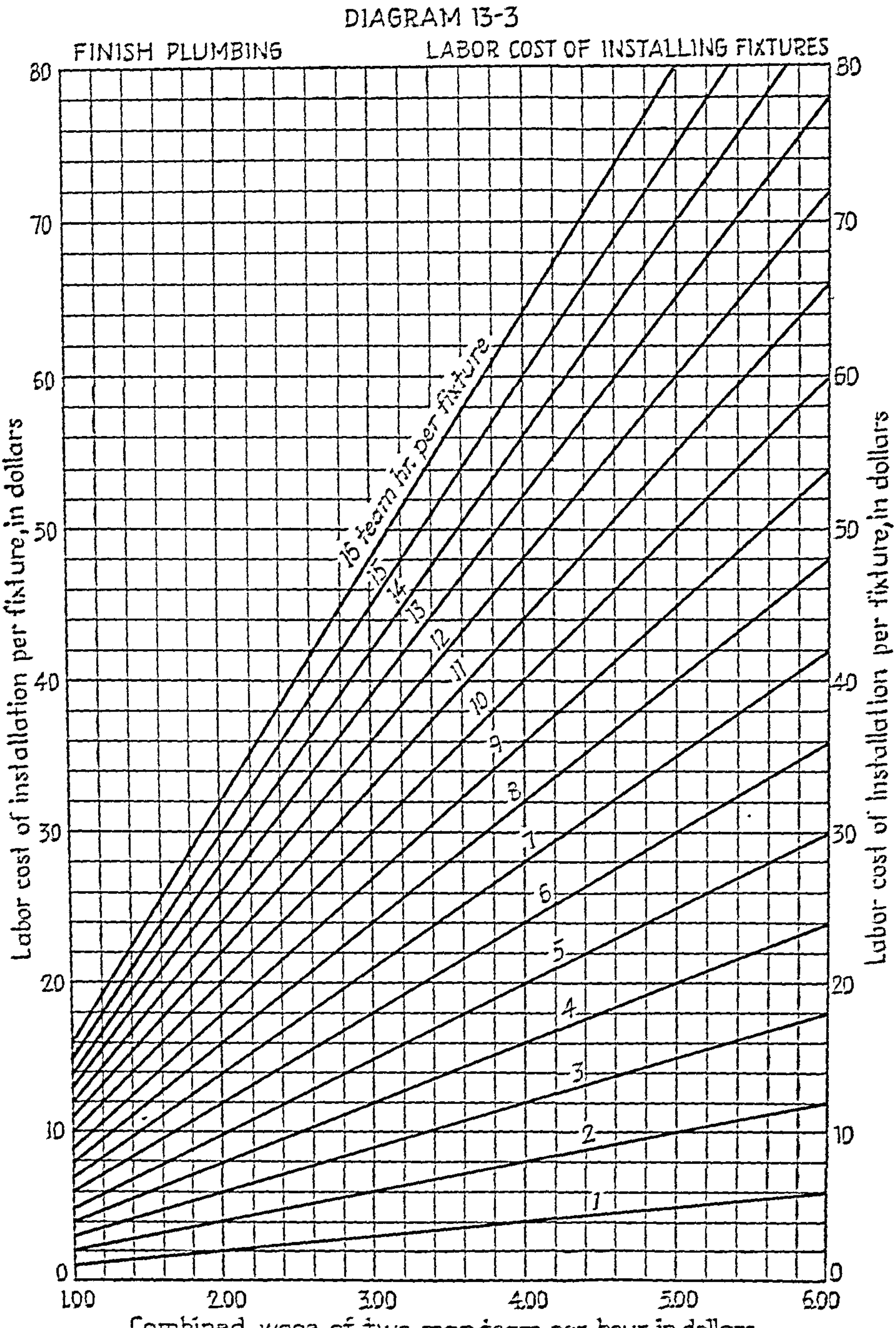

DIAGRAM 13-3.—Labor cost of installing finish plumbing fixtures.

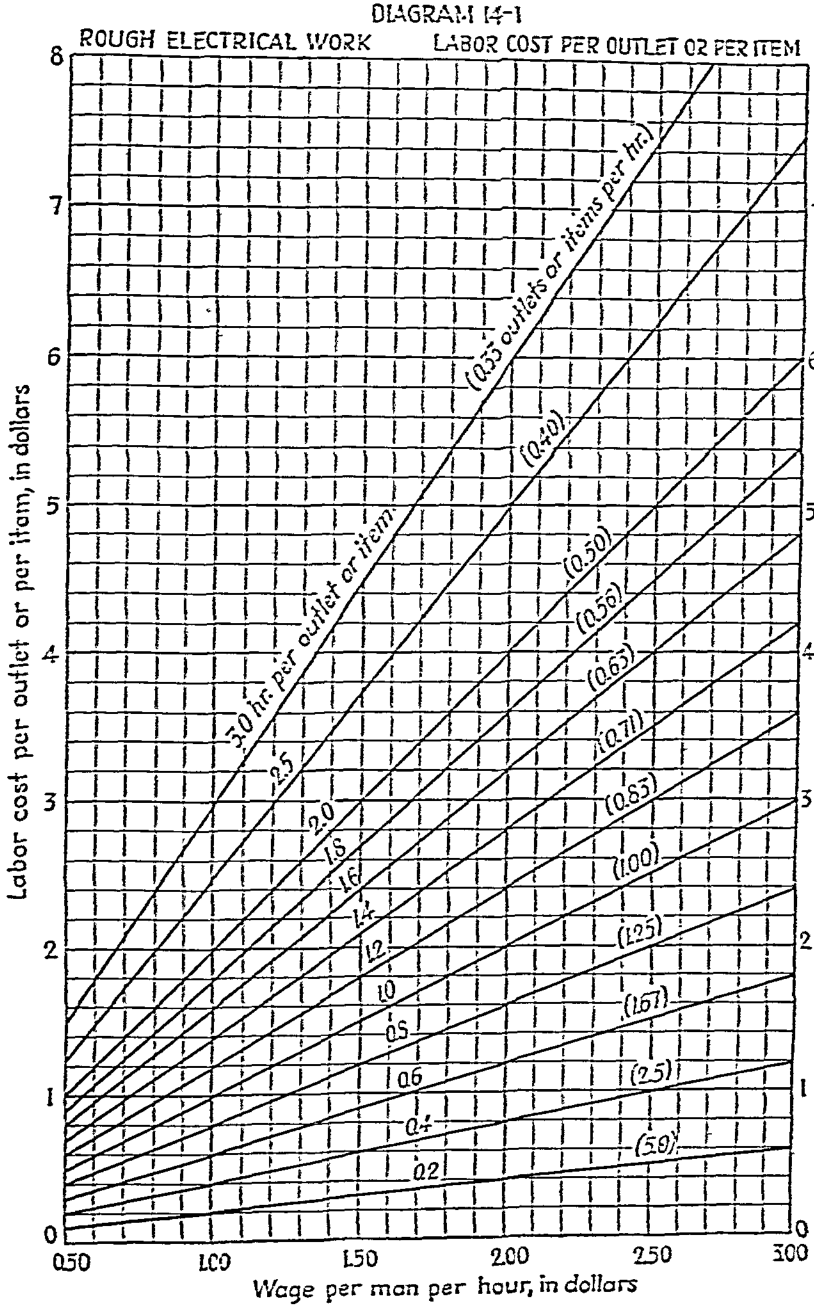

DIAGRAM 14-1.—Labor cost per outlet or per item for rough electrical work.

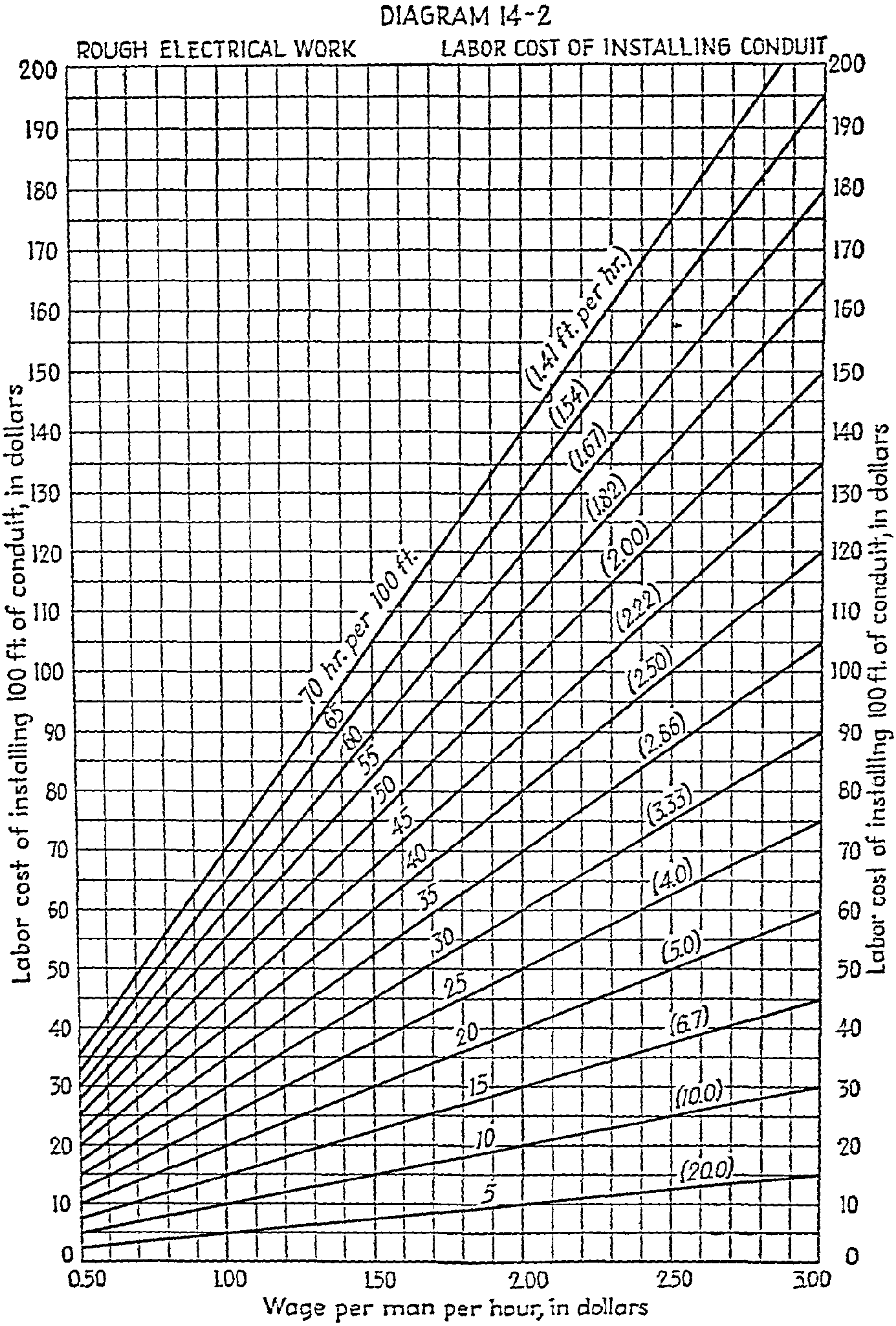

DIAGRAM 14-2.—Labor cost of installing electrical conduit.

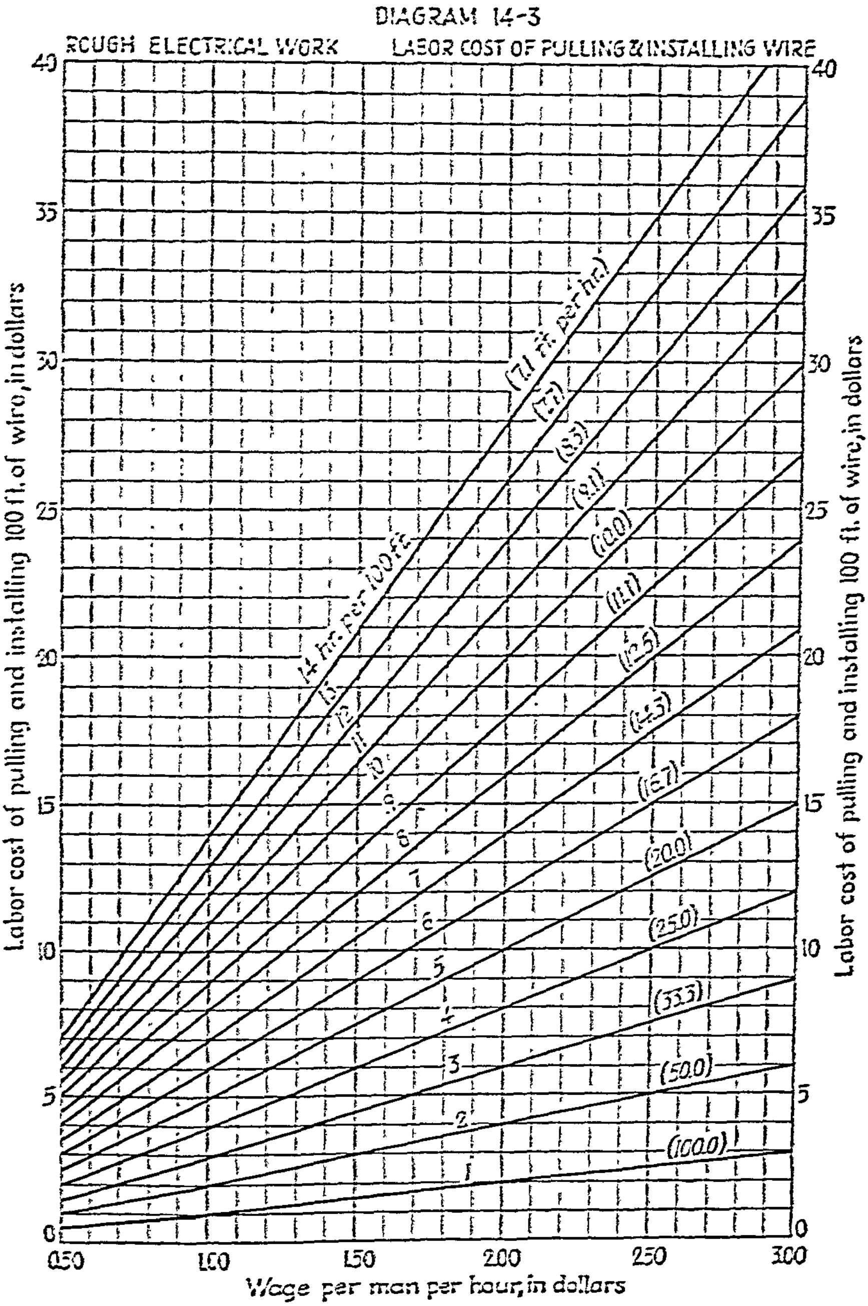

DIAGRAM 14-3.—Labor cost of pulling wire in conduit or of installing wire in knob and tube work.

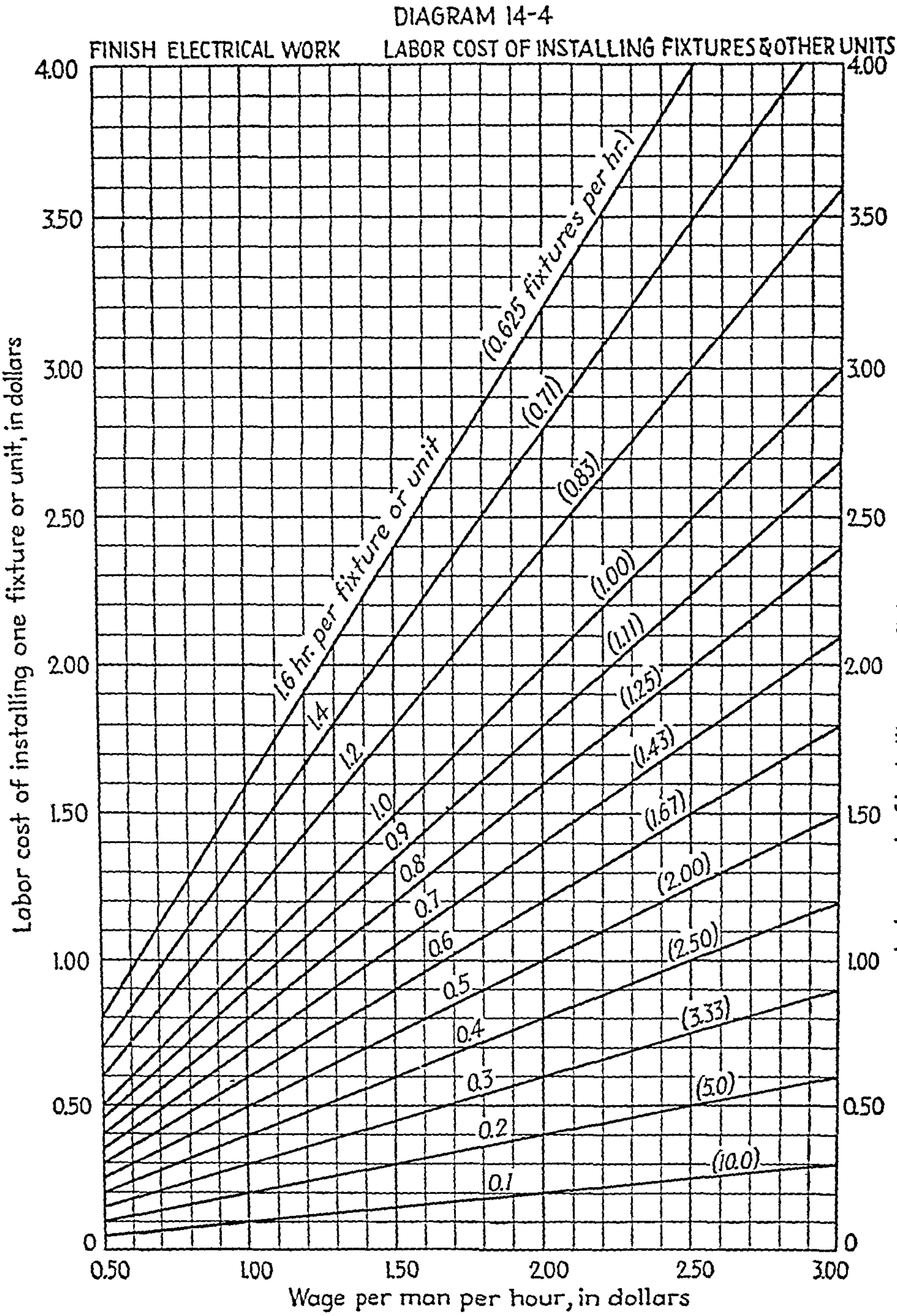

DIAGRAM 14-4.—Labor cost of installing electrical fixtures and other units.

DIAGRAM 15 - 1

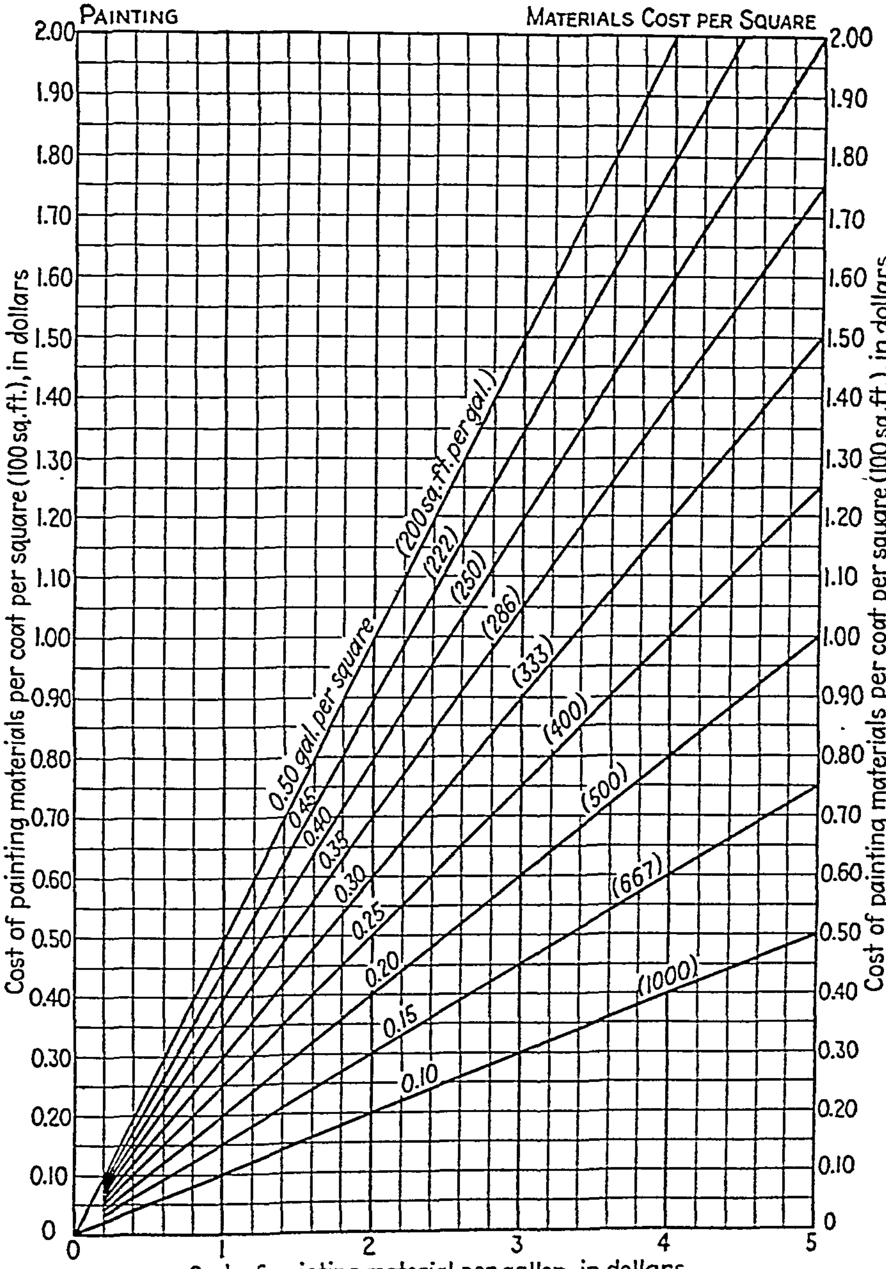

DIAGRAM 15-1.—Cost of painting materials per coat per square of 100 sq. ft. of surface.

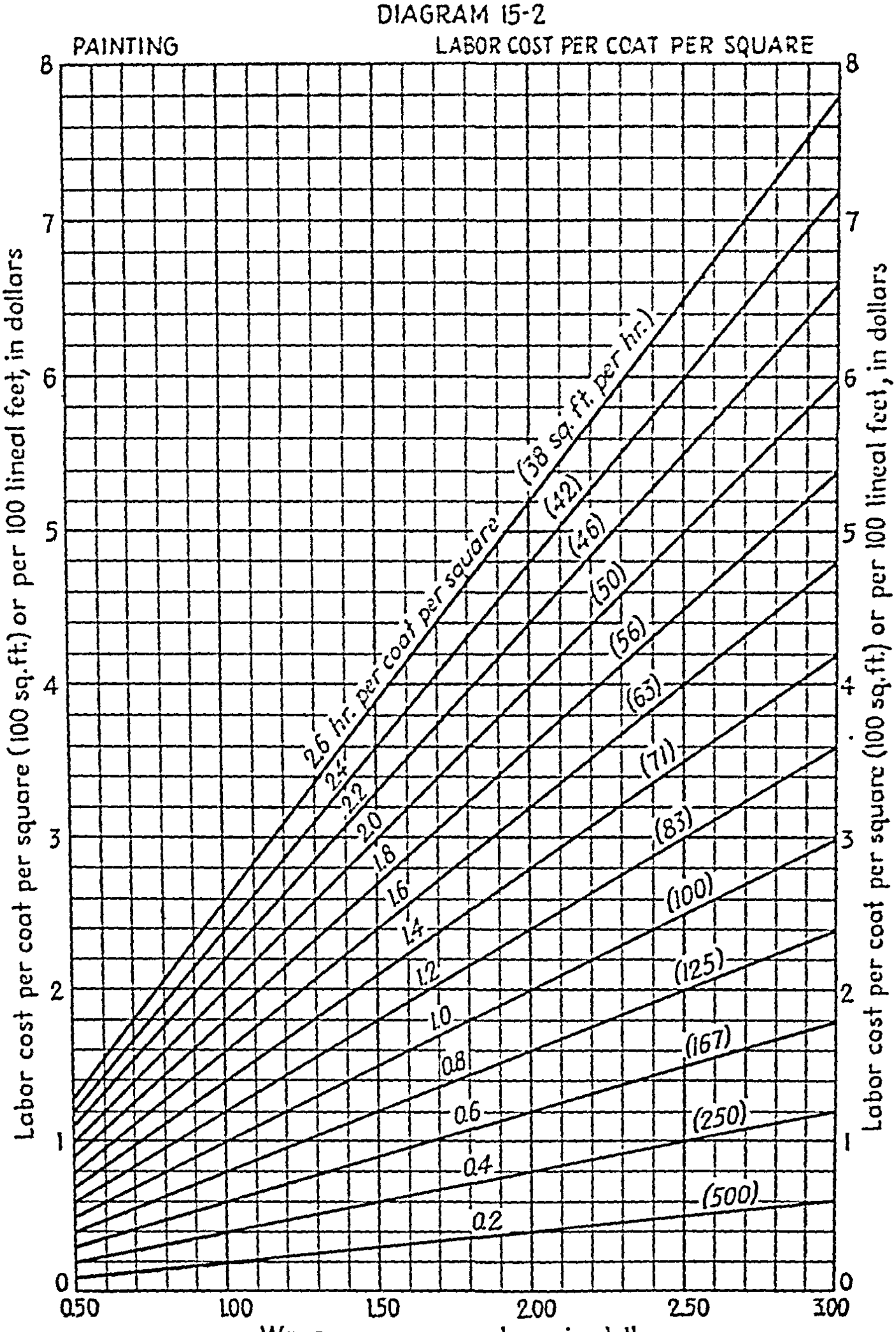

DIAGRAM 15-2.—Labor cost of painting per coat per square (100 sq. ft.) or per 100 lineal ft.

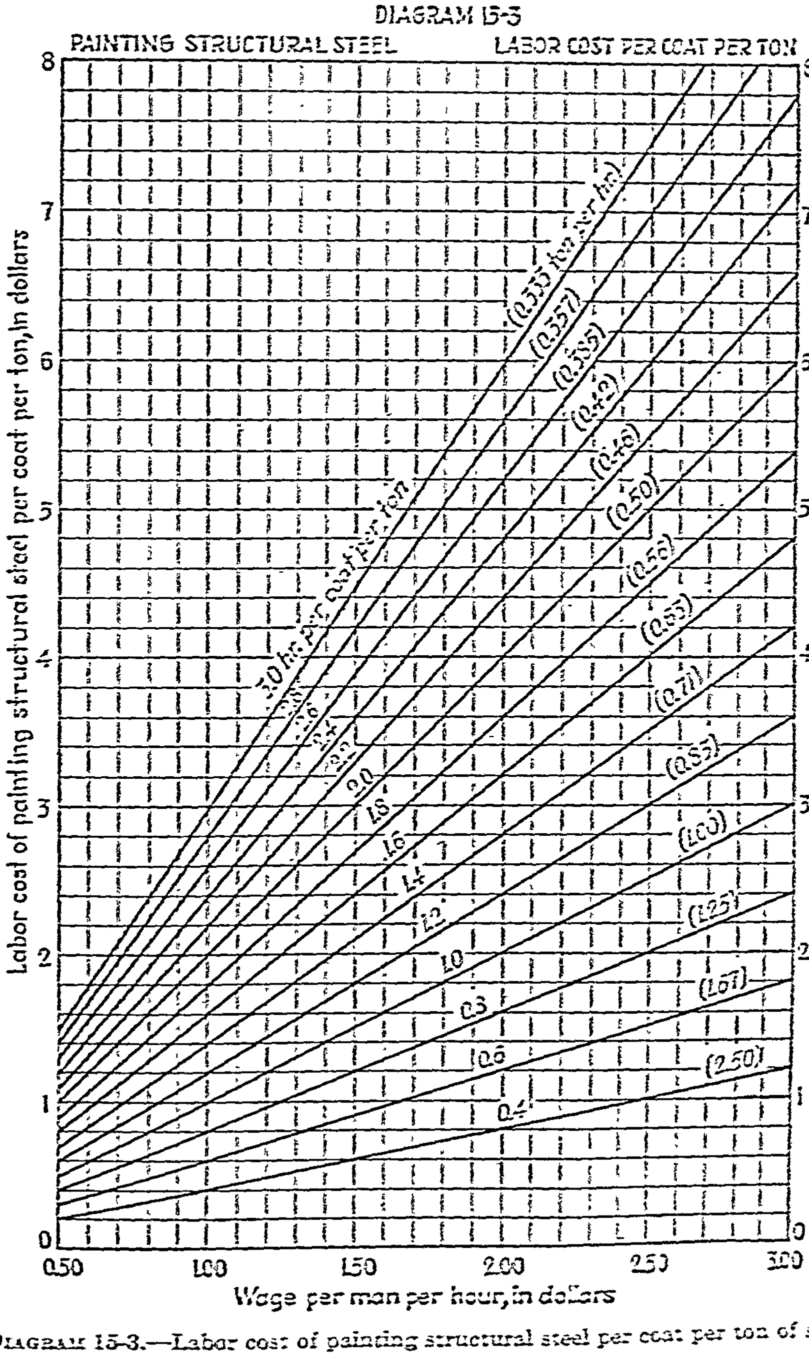

DIAGRAM 15-3.—Labor cost of painting structural steel per coat per ton of steel.

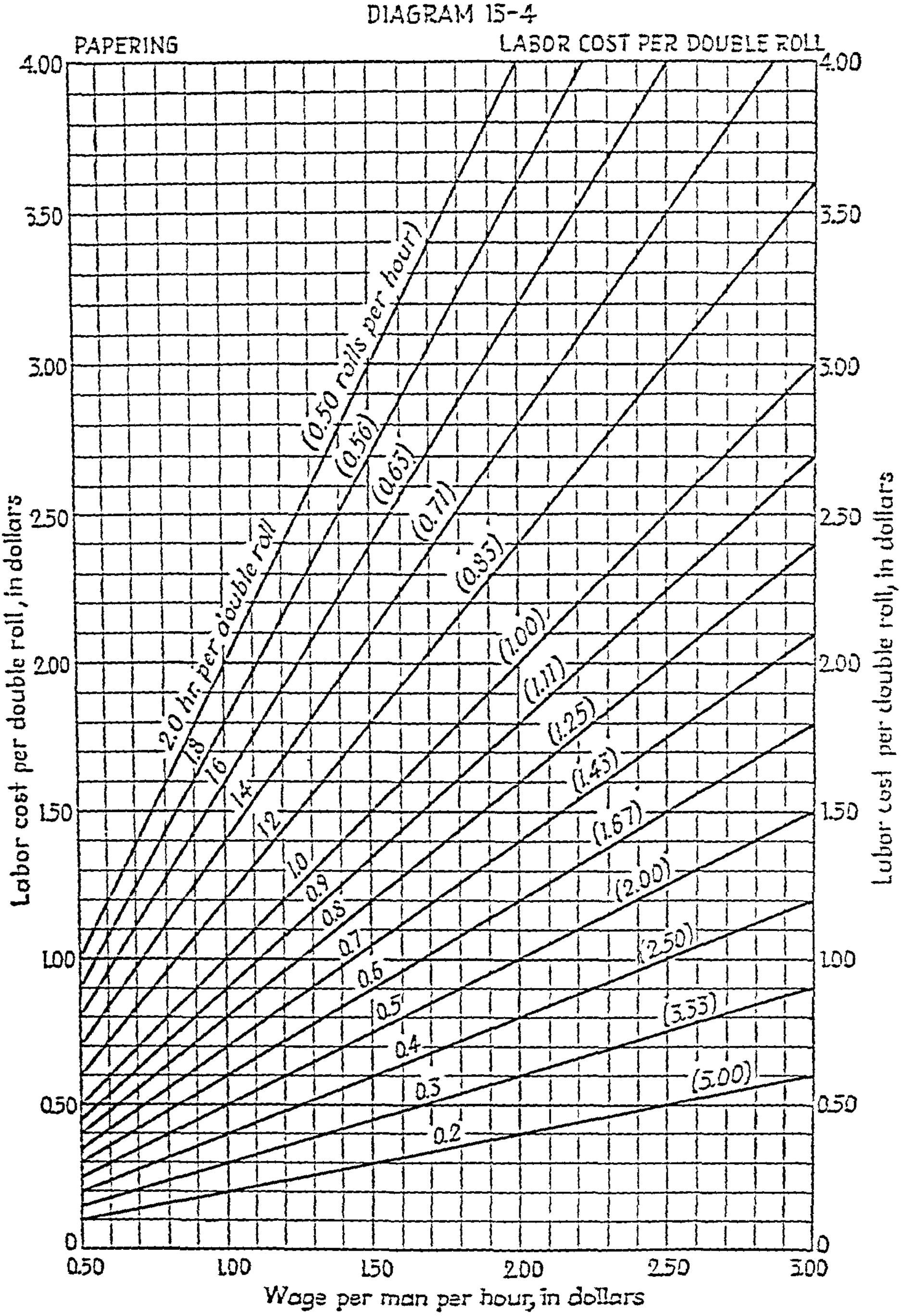

DIAGRAM 15-4.—Labor cost of papering per double roll. Cost per single roll is half of that per double roll.

DIAGRAM 15-5

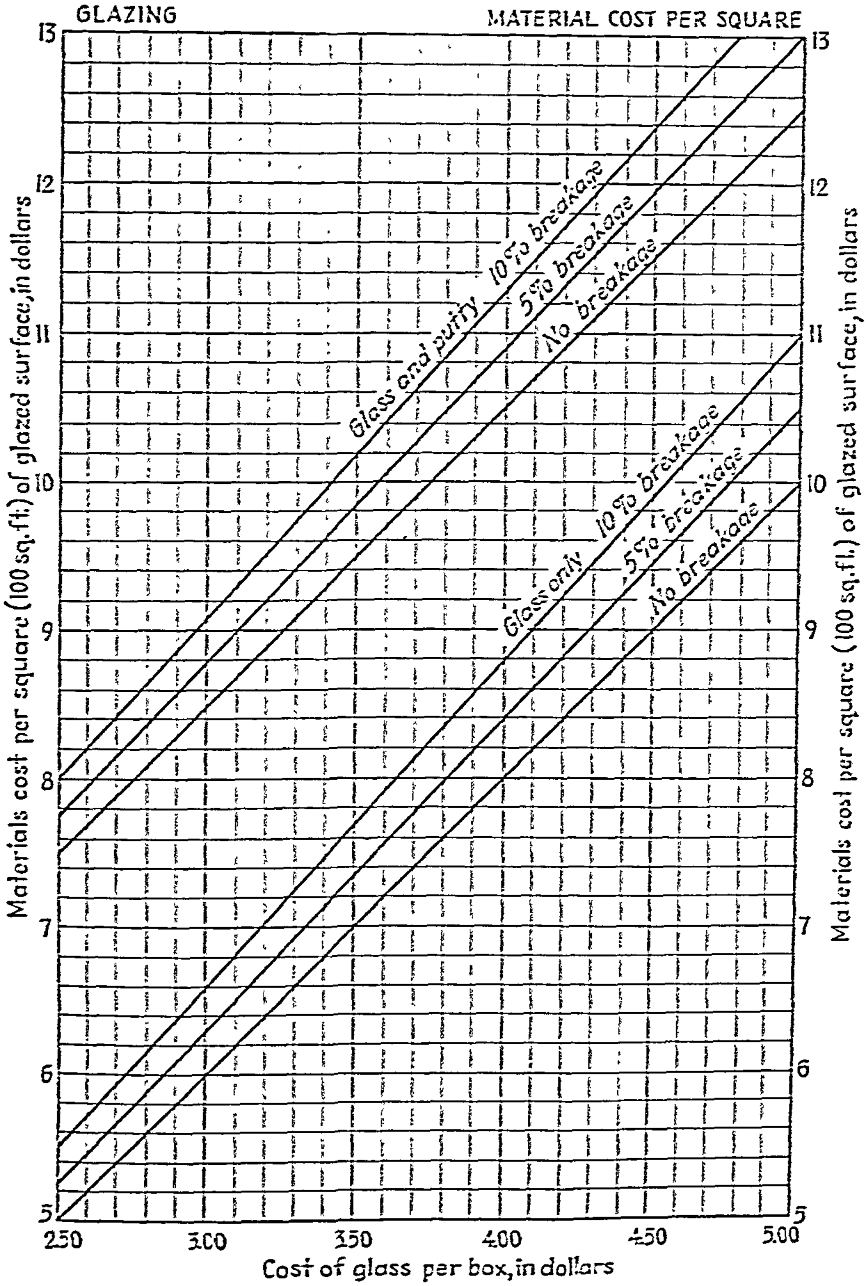

DIAGRAM 15-5.—Materials cost of glass for glazing with allowances for breakage and with and without an allowance of $1.25 per box of glass for putty.

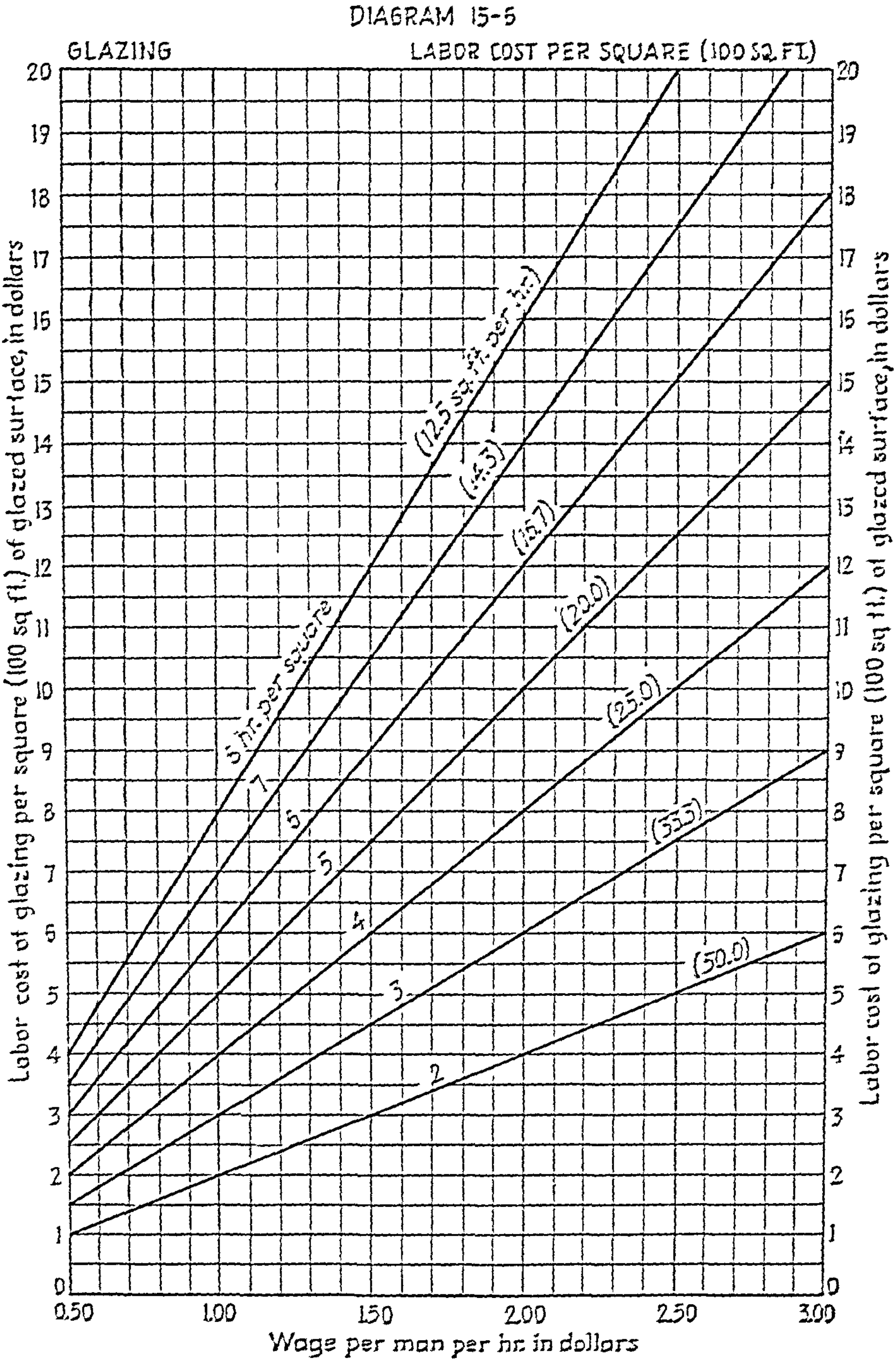

DIAGRAM 15-6.—Labor costs of glazing per square of 100 sq. ft. of glazed surface.

DIAGRAM 15-7

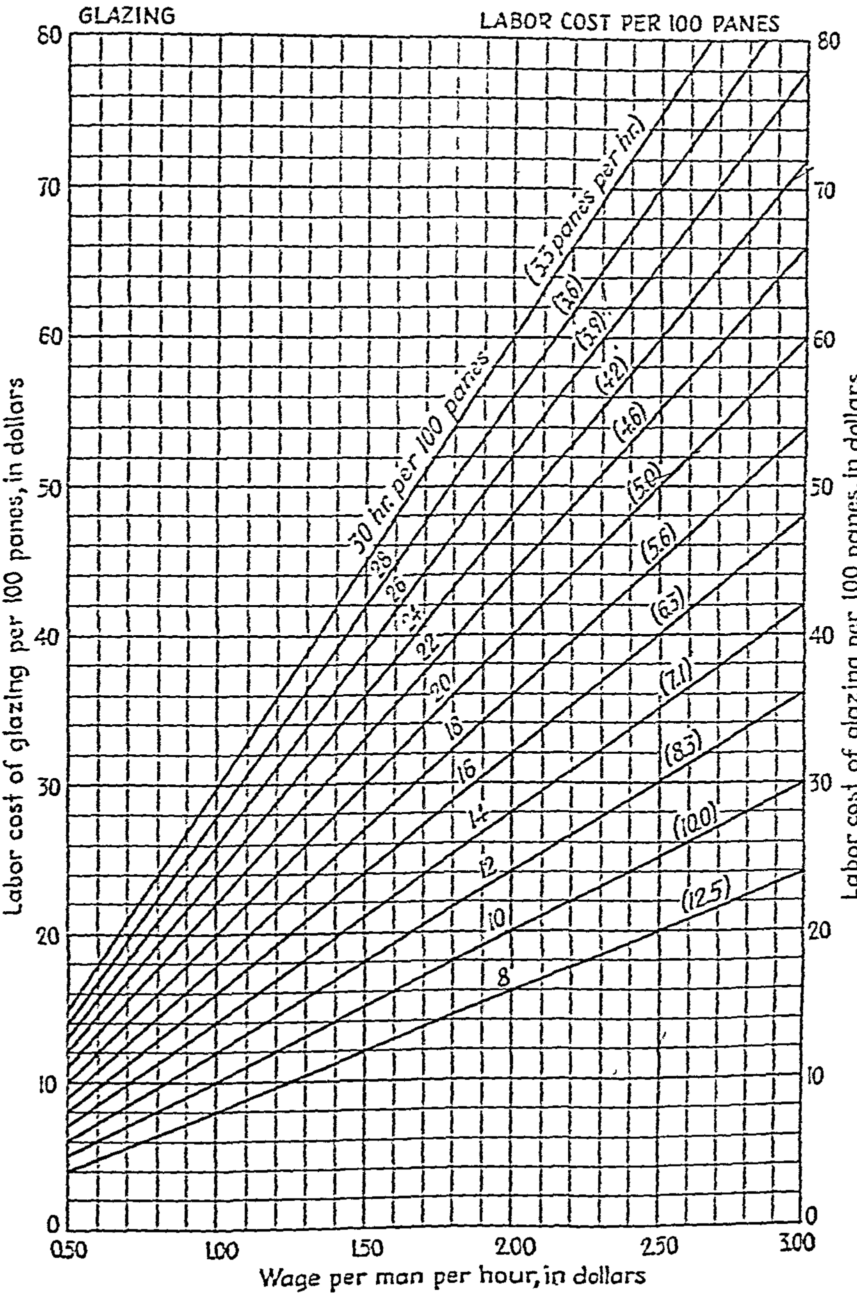

DIAGRAM 15-7.—Labor costs of glazing per 100 panes of glass.

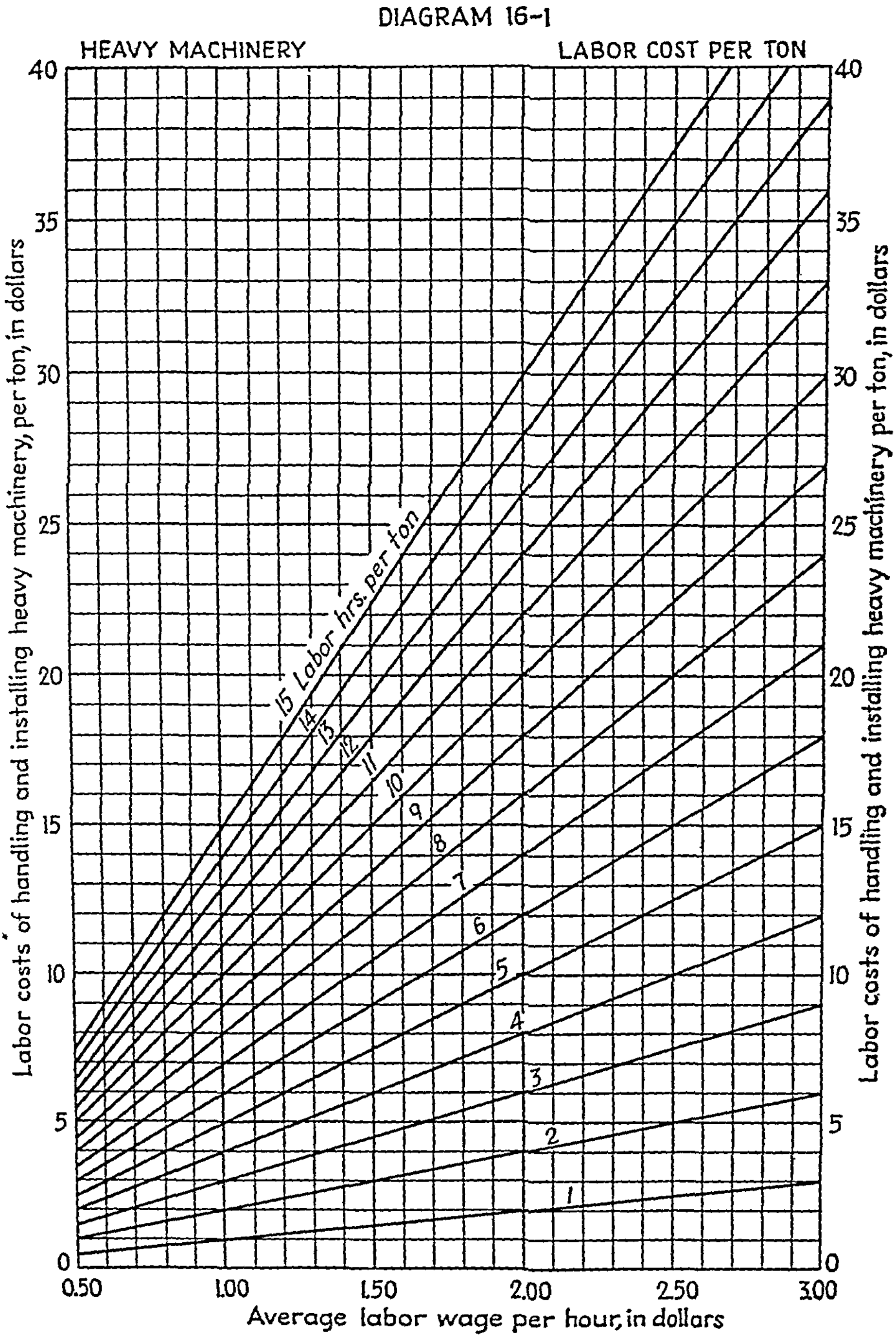

DIAGRAM 16-1.—Labor costs per ton of handling and installing heavy machinery.

DIAGRAM 16-2

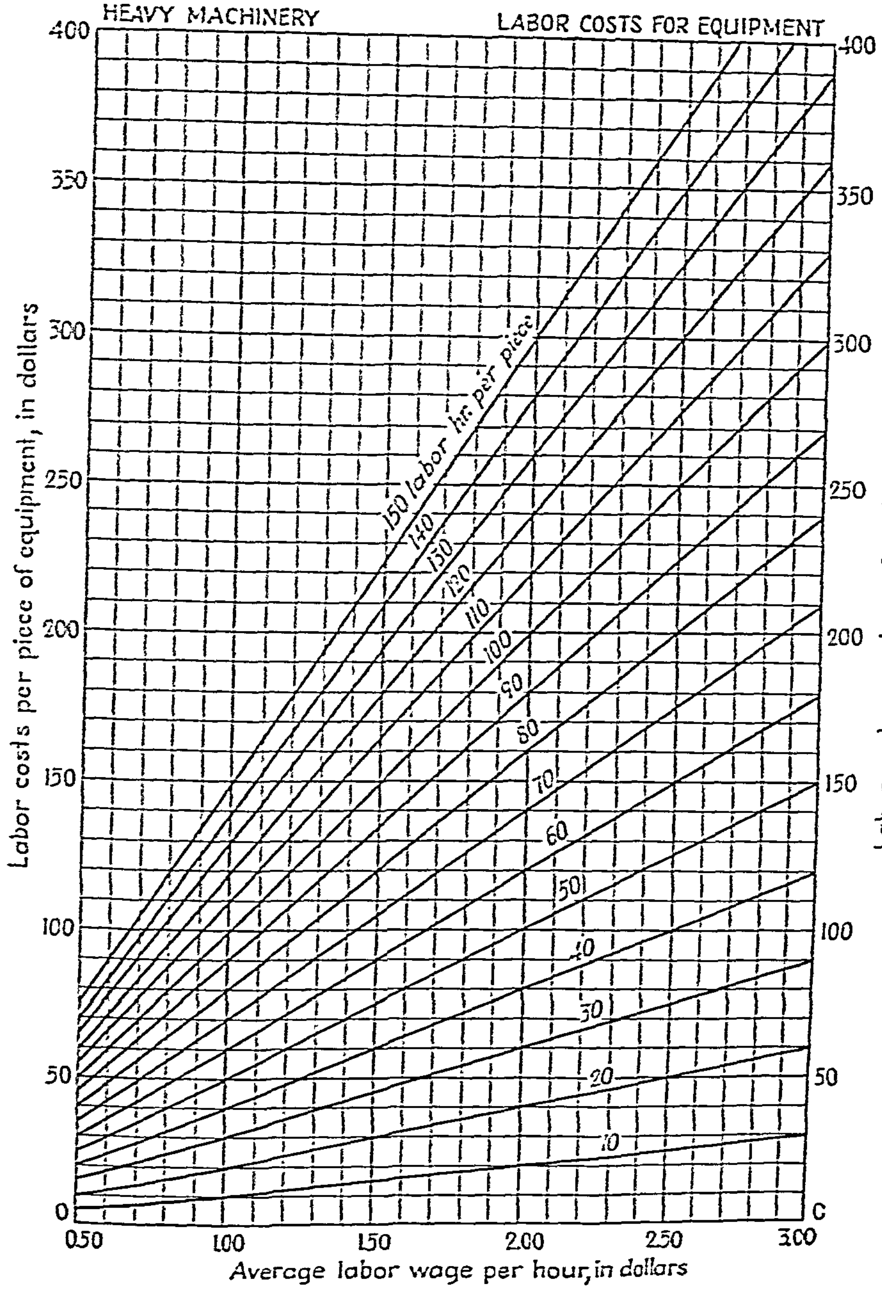

DIAGRAM 16-2.—Labor costs per piece of equipment for loading, unloading, erecting, moving, dismantling, etc.

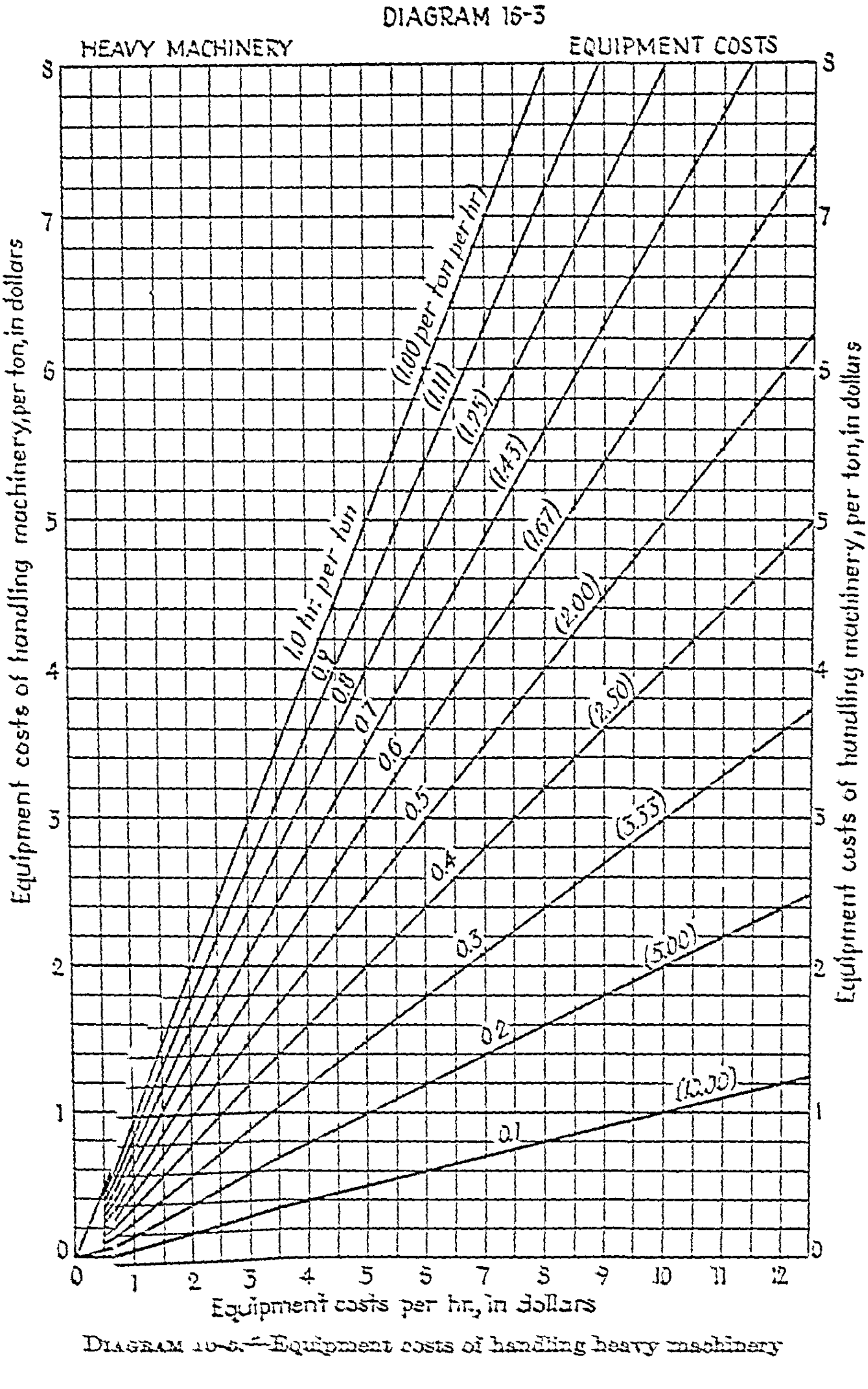

DIAGRAM 16-3.—Equipment costs of handling heavy machinery

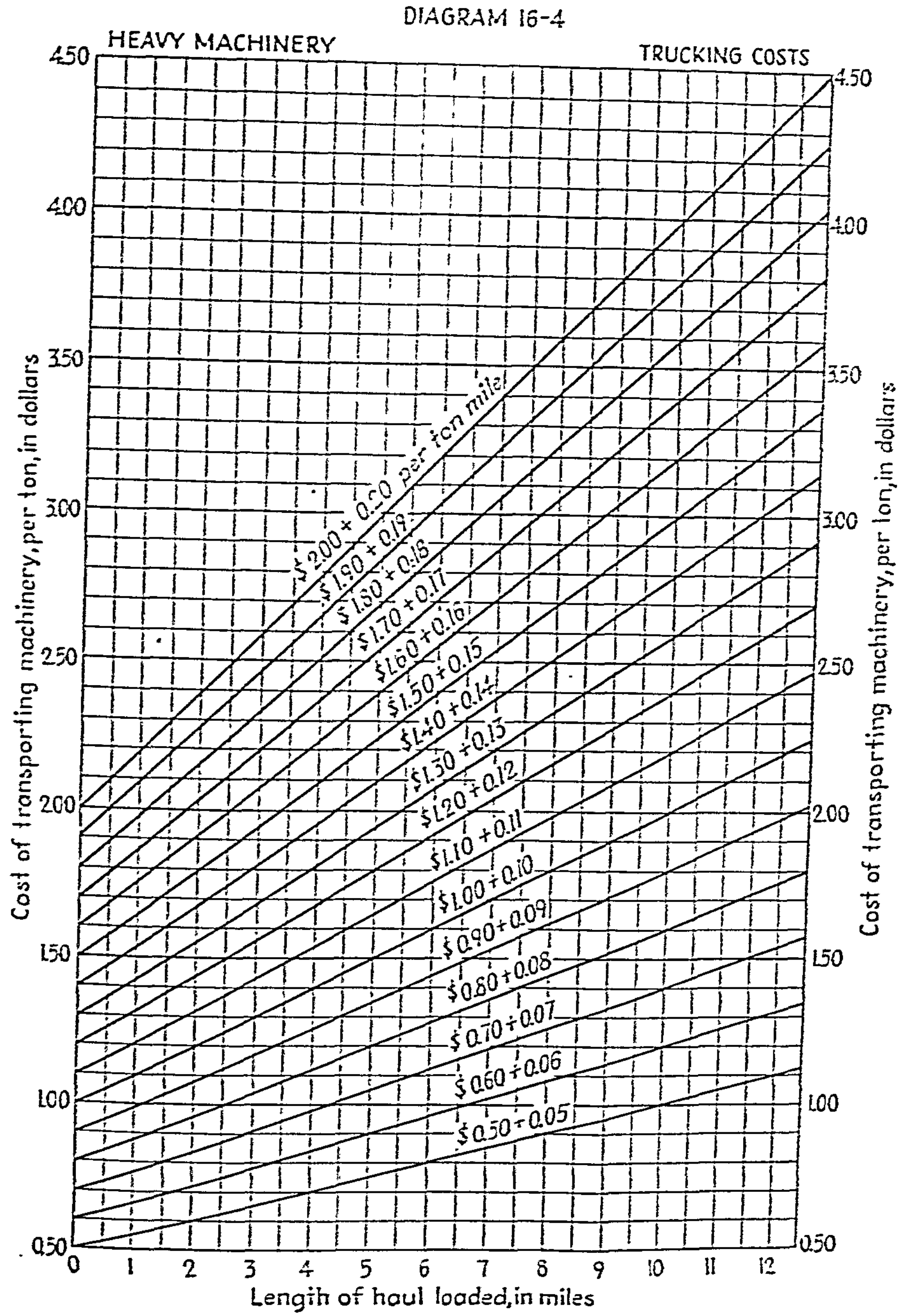

DIAGRAM 16-4.—Costs of transporting heavy machinery by autotruck or by autotruck and trailer.

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The time required for a certain item of plumbing work will vary considerably, depending on the particular work, the working conditions, and the skill and inclination of the plumber. Roughing work for plumbing fixtures may be estimated in labor-hours or team-hours required per fixture without going into further details. Labor for pipework may be more accurately estimated per joint instead of per 100 lin. ft. of pipe, with kind of pipe and diameter given. The labor per joint will include all threading, hanging, and connecting needed. The larger the pipe, the more labor-hours required. It is assumed that an adequate supply of nipples, unions, couplings, and other fittings are available.

Approximate labor-hours and team-hours required for various kinds of rough plumbing work are given in Table 13-11.

When estimating threaded joints, each coupling and valve counts as two joints, a T as three joints, etc. The labor-hours and team-hours given for threaded pipe joints in the table are based on the assumption that one pipe thread must be cut for each joint. When no thread needs to be cut, the time given may be reduced 35 to 50 per cent. Each fitting will require two joints on an average.

The wages for plumbers may vary from about $1.25 to $2.25 per hour, with average values between $1 and $2. Wages of plumbers' helpers may vary from about $0.65 to $1.25 per hour, and in any locality are approximately equal to about half the plumber's wage.

Diagram 13-1 (page 630) may be used for estimating the labor cost of pipe work and Diagram 13-2 (page 631) for the labor cost of rough plumbing work when the hourly combined wage of plumber and helper is known and the time required may be reasonably assumed.

5. Equipment.—The equipment needed will vary with the character and size of the job. Each team may need the following:

Pipe cutters.
Pipe threaders.
Vise, and frame for holding vise.
Workbench.
Wrenches.
Calking tools.
Lead-melting pot.
Lead.